SD11
A55
1948

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
OGDEN, UTAH

ANNUAL REPORT

1948

INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION

REED W. BAILEY
DIRECTOR

RESEARCH PAPERS - INTERMOUNTAIN STATION

No. 1. How to Reseed Utah Range Lands. A. Perry Plummer, R. M. Hurd, and C. Kenneth Pearse. 1943. 22 pp.

No. 2. How to Reseed Southern Idaho Range Lands. A. C. Hull, Jr. and C. Kenneth Pearse. 1943. 22 pp.

No. 3. How to Reseed Nevada Range Lands. Joseph H. Robertson and C. Kenneth Pearse. 1943. 21 pp.

No. 4. Hand Collection and Cleaning of Seed of Native Forage Plants. A. C. Hull, Jr. 1943. 4 pp.

No. 5. Good Seed For Range Reseeding. A. C. Hull, Jr. and C. Kenneth Pearse. 1943. 5 pp.

No. 6. Principles and Indicators for Judging Condition and Trend of High Range Watersheds. Lincoln Ellison and A. R. Croft. 1944. 65 pp.

No. 7. Grazing Management Needed After Accidental Burns. Joseph F. Pechanec. 1944. 2 pp.

No. 8. An Efficient Method of Broadcasting Range Grass Seeds. Joseph H. Robertson. 1944. 3 pp.

No. 9. Experiment Shows Value of Crested Wheatgrass and Rye For Spring and Fall Pasturage. A. Perry Plummer. 1944. 6 pp.

No. 10. Eradication of Big Sagebrush (Artemisia tridentata). Joseph F. Pechanec, A. Perry Plummer, Joseph H. Robertson, and A. C. Hull, Jr. 1944. 23 pp.

No. 11. Seeding Grass on Deteriorated Aspen Range. A. Perry Plummer and George Stewart. 1944. 6 pp.

No. 12. Indicators of Downward Trend on Sagebrush-Perennial Grass Ranges Grazed by Sheep in the Spring and Fall. Joseph F. Pechanec. 1945. 2 pp.

No. 13. Hints For Use Of The Wheatland-Type Plows For Brush Eradication In Connection With Range Reseeding. Joseph H. Robertson and A. Perry Plummer. 1946. 7 pp.

No. 14. Season, Date, and Depth of Planting Crested Wheatgrass and Other Grasses at Lower Elevations In Northern Nevada. Joseph H. Robertson. 1947. 4 pp.

No. 15. An Economic Analysis of Public Grazing Problems in Central Utah. Arthur H. Roth, Jr. 1948. 28 pp.

No. 16. Seeding Southern Idaho Range Lands by Airplane. A. C. Hull, Jr. and George Stewart. 1948. 14 pp.

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION

ADDRESS REPLY TO
DIRECTOR
AND REFER TO

FOREST SERVICE BUILDING
OGDEN, UTAH

R-INT
REPORTS
Annual

April 21, 1949

Dear Sir:

Enclosed is a copy of the 1948 Annual Report of the Intermountain Forest and Range Experiment Station.

We will welcome comments on this report and will be glad to furnish you with additional information upon request.

Very sincerely yours,

REED W. BAILEY, Director

By George W Craddock

Encl.

CONTENTS

Page

Introduction 1

Watershed management and protection. 3
    Soils relations 4
    Plant relations 11
    Water relations 13

Range management research 16
    Summer range 18
    Big game, livestock, and range relationships . . . 21
    Spring-fall range 26
    Winter range 30

Research in range reseeding 33
    Airplane pellet seeding 33
    Species suitability 35
    Methods of seeding and removing competition 38
    Site factors 43
    Plant breeding and strain studies 45
    Grazing studies on crested wheatgrass range 46
    What may be expected from range reseeding 49

Flood control surveys 51

Forest management research 57

Economic research 59

Publications 62

March 1, 1949

INTRODUCTION

As in previous years, the research activities of the Intermountain Station during 1948 were geared both to immediate and long-term needs of land users and, in effect, all citizens of the Intermountain region. The year has seen many of the research projects of the Station move out from the laboratory and testing ground into the wider field of practical application. It has also seen a growing interest on the part of land managers and citizens, locally and even nationally, in several phases of the Station's research program.

There is increasing recognition in the Intermountain West that watersheds in good condition play an important part in the control of runoff and erosion, and by extension, in the control of floods. Without question, much of this recognition has come about because of the precise and detailed information on watershed condition and functioning collected and published by the Intermountain Station. The divisional report on watershed management and protection points out that watershed managers need more of such precise research data in order to evaluate the effects of land use practices on the runoff behavior of mountain lands and to plan for an adequate balance of resource use.

The watershed division has pushed forward its research program to provide answers on the watersheds to the downstream problems of too much, too muddy, or too little water. Solutions have been and are being sought through investigations of soil, plant, and water relations. These include: Studies of infiltration characteristics and of soil stabilization measures; studies of interception and evapo-transpiration losses; and studies of precipitation, stream flow, and sedimentation characteristics.

During the past year, emphasis in the range management research division has been on investigations on summer and winter ranges in central Utah, on big game-livestock range relationships in the State of Utah, and on spring-fall ranges in southeastern Idaho. For more effective grazing management, studies have been directed toward answering such questions as: What degree of plant cover and what species composition should be the goal on specific types of range? How should ranges be classified as to condition? What are the indicators of trend on these ranges and what do they mean? How much forage utilization is permissible? What plants should be used in judging utilization? Answers to these and similar questions on some types of range are emerging and are presented in more detail in the range management divisional report.

The reseeding research division is continuing investigations on most suitable grass species for various sites throughout the Intermountain region, on methods of seeding and reducing competition, and on the influence of site factors in obtaining grass stands and producing forage. An important project to test the effectiveness of airplane pellet seeding in comparison with other seeding methods was begun in 1948 on the LaSal division of the Uinta National Forest. First phases of the experiment are now complete, including seeding, establishment of control plots for the different seeding methods, and laboratory tests on germination of pelletized and unpelletized seeds. Yield data for the various treatments will be taken as soon as the seeded species are well established. Demand is high for published information on all phases of reseeding within the region as well as from other parts of the West.

Work in the flood control surveys division, both in the preparation of reports and field surveys, was carried out in accord with the general plan for the year. This was true even though numerous special studies were also assigned. Notable among these were the basin-wide survey of the Missouri River basin which was done in cooperation with the Soil Conservation Service and the Forest Service study of the Columbia River flood early in the year. Accomplishments are detailed in the divisional report.

Forest management research needs for the Intermountain region have been analyzed and a complete research program is being formulated. A report on reproduction and stocking of ponderosa pine areas in Idaho was finished in 1948 and was presented to the Regional office for review. The more important conclusions of this report and information on other projected studies are summarized in the divisional report.

An analysis of the major range economic problems in the region was completed early in 1948. The subject that received first attention was that of the cost of reseeding range land. Plans were also made to tackle some of the other problems in an area study of the place of range resources in the changing economy of Utah. Throughout the year the Station economist was called on to supply a wide variety of facts to aid in solving the many post-war forest and range problems of the region.

Cooperative work in flood control surveys, on reseeding investigations, and on big game-livestock range relationships was conducted with the following Federal and state agencies:

Bureau of Land Management
Bureau of Plant Industry, Soils, and Agricultural Engineering
Soil Conservation Service
Utah State Agricultural Experiment Station
Utah State Fish and Game Commission
U. S. Fish and Wildlife Service

The contributions of each of these cooperating agencies are specified in pertinent sections of the various divisional reports which follow.

WATERSHED MANAGEMENT AND PROTECTION

The people who live in the semiarid valleys of the Intermountain region are faced with three serious water problems, all of which are traceable to the hydrologic behavior of the mountainous forest and range lands that flank the valleys. One of them is the problem of floods, including those which occur as violent debris flows during torrential summer storms and those which occur as more prolonged discharges during snow melt in the spring. A second problem is that of sedimentation in the region's reservoirs, canals, water systems, and river channels as a result of soil displacement on the watershed slopes and of channelling in canyon bottoms. A third problem is that of a shortage of usable water due to low yields from the mountain lands during the late summer and fall seasons.

These downstream problems of too much, too muddy, and too little water pose important questions in watershed management. It is known that there is great variation--from place to place and in time--in the runoff characteristics of mountain lands. Watershed managers need much more knowledge on what these normal limits are as a base line from which to plan resource use and to evaluate the effects of land use practices on the runoff behavior of the mountain lands. It is known that depletion of plant cover and soil disturbance can lead to greater floods and sedimentation. However, watershed managers do not yet know with sufficient accuracy where, how, and to what extent the forage and timber resources on the mountain lands can be utilized without adversely affecting the usefulness of stream flow. It is known that many watershed lands are in a seriously deteriorated condition--but knowledge is lacking on how to restore the normal hydrologic functions of those lands. It is known, too, that vegetation consumes water which might otherwise become stream flow and that the shading effect of forests retards snow melting. An important question remains, however, as to whether the naturally low flow of streams in the summer and fall can be increased by cultural treatment of the plant cover on the watershed slopes without increasing flood peaks and sediment loads.

Further progress toward the solution of these watershed management problems was made during the past year through a continuation of forest influences research at the Great Basin, Wasatch, and Boise Research Centers. Solutions were sought in part through investigations of soils relations, including studies of infiltration characteristics and of soil stabilization measures. The program also embraced investigations of plant relations including studies of interception and evapo-transpiration losses, and investigations of water relations, including studies of precipitation, stream flow, and sedimentation characteristics. Highlights of the results of these studies and plans for further effort are as follows.

SOILS RELATIONS

Much of the unsatisfactory behavior of streams in the Intermountain region stems from the character of the soil mantle on the watershed slopes. These lands are subject to high intensity summer rains. Precipitation from these storms that is not absorbed by the soil mantle, produces runoff in the form of overland flow. This kind of runoff is a powerful eroding agent and can generate violent discharges capable of scouring deeply filled canyon bottoms and of causing direct flood damage on developed downstream flood plains.

A single summer storm can drastically change the hydrologic functions of the soil. For one thing, a storm that causes greater than normal soil erosion reduces the water storage capacity of the soil mantle. Moreover, the carving of rills and gullies increases the efficiency of the land to lose water by drainage, overland flow, and evaporation. Such changes, once set in motion, step up the opportunities for more frequent and increasingly larger summer storm discharges, and favor increasingly high stages of stream flow during the period of melting snow. It is clear, therefore, that watershed protection requires the maintenance of conditions that favor the maximum possible infiltration rates in the soil mantle and the greatest possible stability of the soil.

Infiltration

Maintenance of favorable infiltration conditions is a highly localized problem--one that requires consideration of virtually every square foot of watershed surface. Timber is harvested tree by tree and forage is grazed plant by plant. Even roads are extended foot by foot. All of these treatments directly affect the reception of precipitation spot by spot, and drastic alteration of even limited areas is known to be responsible for the development of serious flood and sediment sources.

In keeping with the localized nature of the problem, this Station has used a direct approach toward the determination of watershed protection requirements. In this approach, type F infiltrometers are used to subject sites to artificial rainfall comparable in volumes and intensities to those of expected major storms. Resultant amounts of runoff and eroded soil are related to observable and measurable characteristics of the sites. These relationships provide a quantitative basis for determining the specific characteristics of the plant cover and soil mantle that are required for control of overland flow and erosion, site by site.

Protection Requirements of Granitic Soils

Continuation of infiltrometer studies on the Boise River watershed throw further light on the protection requirements of the loose, coarse-grained, granitic soils on the steep mountains of south central Idaho. Detailed analyses of data obtained from exploratory tests on undisturbed wheatgrass and downy chess range sites in 1947 were completed. Additional field tests were made in 1948 to determine the capacity of these range lands to cope with very high rainfall rates under conditions of no soil disturbance and under conditions simulating heavy trampling by livestock.

In the 1947 tests, 14 wheatgrass and 16 downy chess sites which had been protected from grazing for 17 years were subjected to 1.80 inches of artificial rainfall at the moderately high rate of 3.60 inches per hour. Amounts of overland flow and eroded material were related to the following site characteristics:

(1) Ground cover density--percent of soil surface covered by plant basal area and litter, (2) bare soil--the average maximum distance in inches across bare soil openings, (3) amount of erosion pavement, (4) plant cover density--percentage of land surface shaded by the aerial portion of plants, (5) soil profile depth, (6) abundance of roots, (7) soil pore space, and (8) slope gradient.

Overland flow from the wheatgrass sites during the 1947 tests varied from zero to nearly 28 percent and eroded soil ranged from zero to the equivalent of 3,358 pounds per acre. The downy chess sites produced overland flow ranging from about 4 percent to 42 percent and eroded soil varying from 462 to 3,620 pounds per acre. These results are essentially similar to those obtained on similar sites by Craddock and Pearse in 1936. The tests also revealed some important relationships between variations in the site characteristics and the runoff and erosion behavior of the two range types.

Analyses of these data showed ground cover density and size of bare soil openings to be the two site characteristics which dominantly control amounts of overland flow and soil erosion from both of these range types. While the amount of erosion pavement, plant cover density, soil depth, and soil pore space were related to overland flow and erosion in each case, they are so closely correlated with ground cover density that their effects are obscured by the effects of the latter characteristic.

Removal of the aerial portion of the plants by clipping had no significant effect on overland flow or erosion. The lack of effect of this treatment is believed to be due to the presence of an accumulation of litter beneath the crown spread of the plants which, evidently, was as effective in protecting the site as the plant canopy. Increase in slope gradient within the range of 35 to 60 percent appeared to have no definite effect either, probably because the 6 x 6-foot test plots were too short to permit concentration of overland flow such as is possible over longer slope distances.

Further analyses revealed the two site characteristics of amount of ground cover and size of bare soil areas to have rather sharply defined limits for controlling runoff and erosion under conditions of nondisturbance from trampling and moderately high rainfall rates. Overland flow and erosion from both range types rapidly increased with a decrease in ground cover density below

70 percent. Ground cover densities greater than 70 percent were not materially effective in reducing either overland flow or erosion. Overland flow and erosion also increased as the size of bare soil areas increased, but they decreased rapidly when the size of bare soil areas was less than 10 inches across. Bare soil openings of 4 inches or less in diameter are normally associated with ground cover densities of 70 percent or more in these two range types.

The occurrence together of at least 70 percent ground cover and bare soil openings of not more than 4 inches across appears to be necessary for protection of undisturbed wheatgrass and downy chess range lands on the coarse, granitic mountain soils of south central Idaho. With these conditions prevailing, rains of 1.80 inches falling at rates up to 3.60 inches per hour may be expected on the average to produce 4.9 percent runoff and 490 pounds of eroded material per acre from the wheatgrass type; and from the downy chess type, average runoff will be 4.8 percent, and soil displacement, 565 pounds per acre.

Data from additional field tests made in 1948, though not yet fully analyzed, appear to substantiate the 1947 findings. That is, the wheatgrass and downy chess types in undisturbed condition are about equally effective in controlling overland flow and erosion during storms of moderately high intensity (3.60"/hr.), providing the ground surface is covered to the extent of 70 percent or more. The wheatgrass type, in undisturbed condition, is superior to the downy chess type for protection against rainfall rates of about 6.50 inches per hour, a ground cover density of 70 percent still being effective. Under conditions of heavy trampling disturbance, the wheatgrass type is also more effective than the downy chess type under the impact of 3.60 inches per hour rainfall rates, providing ground cover densities are 80 percent or more. Neither range type will provide effective protection against rainfall rates as high as 6.5 inches per hour when the sites are drastically disturbed.

It is planned to continue these tests to determine whether less intensive trampling disturbance can be tolerated in the grassland, spring-fall range types on sites which now appear to afford effective protection when undisturbed. These tests should provide a sound basis for establishing the protection requirements of these types. Time permitting, studies will also be extended to the Stipa-Lupine summer range type for the purpose of developing protection criteria for that type.

Protection Requirements of Herbaceous Range on Clay Soils

A similar approach to that used on the very coarse granitic soils of Idaho is being followed to determine the protection requirements of herbaceous range on the more dense clay soils of the Wasatch Plateau in central Utah. This effort has centered on the A and B experimental watersheds at the Alpine substation of the Great Basin Research Center near the head of Ephraim Canyon.

Last summer, infiltrometer tests were made on 14 sites representing a wide range of ground cover conditions with the ungrazed Area A experimental watershed. As in the previous years tests, each of the 6x6-foot plots was subjected to 1.50 inches of rainfall applied at rates of about 6.00 inches per hour, during which overland flow and eroded soil were measured. In these tests, overland flow varied from zero or negligible amounts on plots having a plant and litter cover of 96 to 100 percent, to as much as 93 percent on sites having a ground surface cover of from 16 to 40 percent. Losses of eroded soil varied from negligible amounts on the most densely covered sites to as much as 131 tons per acre per hour on the thinly covered sites.

When the 1948 data are added to those obtained in similar tests made in 1947 and 1945, a striking relationship between ground cover density and erosive runoff becomes apparent. On the average, runoff increased from zero to about 20 percent as ground cover was reduced from 100 to 65 percent. This is equivalent to an average runoff increase of about .5 percent for each 1 percent reduction in ground cover. With further reduction in ground cover to 40 percent, the amount of runoff increased to about 85 percent. Thus, reduction of ground cover density below 65 percent resulted in about a five-fold acceleration in the rate of runoff per decreased unit of ground cover. Still greater amounts of runoff occurred with ground cover densities less than 40 percent, though the rate of increase per unit of decreased ground cover was less.

The very marked acceleration in rates of runoff with ground cover densities of less than 65 percent closely approximates the behavior of the undisturbed wheatgrass and downy chess range types on the coarse granitic soils of southern Idaho. However, 65 percent ground cover on the clay soil results in about 20 percent runoff as compared to only about 5 percent on the granitic soils. Though 65 percent ground cover on the clay soil of the Wasatch Plateau evidently defines a level below which further reduction in ground cover will result in greatly accelerated runoff, it is believed that management should seek to achieve ground cover densities in the order of about 75 percent or more in order to keep runoff well below 20 percent during major storms.

The effect of current trampling on runoff and erosion has not yet been adequately tested on these heavy clay soils. Tests thus far indicate, however, that ground cover densities in excess of 65 to 75 percent will be needed to offset the affects of soil compaction and reduced infiltration capacity caused by livestock trampling. It is planned to obtain additional tests of the effects of trampling as a basis for more accurately defining the protection requirements of this type of summer range.

Soil Stabilization

Extensive portions of the mountain lands in this region are known to be eroding at accelerated rates because of depletion of the plant and litter cover induced mainly by overgrazing. Managers and users of these lands are faced with the question as to whether satisfactory watershed conditions can be expected through natural revegetation or whether supplemental measures are required.

Soil Stabilization by Natural Revegetation

A test of the effects of natural revegetation on the stabilization of eroding soil has been under way since 1915 on the 10-acre A and B experimental watersheds at the Great Basin Research Center. In the first period of this experiment (1915-23) the average density of the herbaceous plant cover on area A changed from an initial low value of 16 percent to about 30 percent, largely as a result of protection from grazing. The average plant cover density on area B was maintained at 40 percent through moderate grazing. In the second period of the test (1924-1934) average plant cover density was maintained at about 40 percent on both watersheds. In the third period (1935-1947) continued protection from grazing has resulted in a further improvement of the plant cover on area A to an average density of 50 percent. Area B, however, has been overgrazed to reduce the average plant cover density to 20 percent. The alterations in the plant cover have resulted in profoundly different runoff and erosion behavior during the three test periods, as shown in the tabulation below:

Test periods.	1915-1923		1924-1934		1935-1947	
Watershed areas	A	B	A	B	A	B
Av. plant density (pct.) . .	16-30	40	35-40	40	40-50	35-20
Av. an. runoff (c.f./a.) . .	795	122	327	73	325	482
Av. an. soil loss (c.f./a.) .	109	18	14	4	18	46

These data show that area A, while in seriously depleted condition in the first period, produced about 6.5 times more runoff and 6.1 times more eroded soil than area B. During the second period, after the average plant cover density on area A had become about equal to that on area B, area A still produced 4.5 times more runoff and 3.5 times more eroded soil than area B. In the final period, during which the average plant cover on area A continued to thicken while that on area B was being reduced, area B produced 1.5 times more runoff and 2.5 times more eroded soil. The complete reversal in the runoff and erosion relationships leaves no room for doubt that plant cover exerts a dominant effect on the runoff and erosion behavior of these watersheds.

Though an increase in the average plant cover density on area A from 16 percent to 50 percent has resulted in some reduction in storm flow runoff and soil loss, the area is far from satisfactory for watershed protection purposes. Detailed observations and infiltrometer tests show that only about 6 percent of the area has attained a plant cover that is capable of keeping the soil in place. About 43 percent of the area has reached a stage that may be termed fairly satisfactory. Very unsatisfactory conditions continue to prevail on 51 percent of the area.

The latter areas, with a plant cover of generally less than 30 percent, are continuing to deteriorate. These areas produce overland flow and lose soil when subjected to rains of as little as .05 inch. During high intensity rains, gullies are carved 1 to 2 inches deep at intervals across the slope of a foot or less. Runoff from these areas also carries away seed. Fifteen seedlings germinated in one 150 gram sample of eroded soil. Out of 12 samples observed, 7 produced seedlings.

The conditions and behavior of area A after 5 years of very light grazing and nearly 30 years of no grazing makes it clear that natural revegetation cannot be depended upon to stabilize soil on slopes where the plant cover has been depleted to densities of 30 percent or less. Stabilization of such areas requires intensive supplemental measures, such as contour trenching, gully plugging, mulching, and seeding.

Detailed analyses of the 1915-1948 precipitation, runoff, and erosion records on the A and B experimental watersheds are now nearing completion. These data, together with those to be obtained in 1949, will be used as a basis for a comprehensive report covering the entire period of the experiment. Inspection of the results to date indicates the next most fruitful use of area A will be to use it to test the effectiveness of intensive watershed improvement measures.

Soil Stabilization on Flood Source Areas, Wasatch Front

The erosion behavior of typical summer storm, mud-rock flood source areas has been under observation at the Wasatch Research Center near Farmington since 1936. At that time batteries of 1/40-acre runoff plots equipped with sediment traps were installed on very deteriorated herbaceous and shrubby sites. In addition, 1/10-acre plots were established on more densely covered aspen sites from which there apparently had been little storm flow runoff or soil loss.

The runoff plots were not disturbed or treated during the 11-year period 1936-46, inclusive. There were 21 runoff producing summer storms in that period, including one in 1936 that attained a rate of 5.04 inches per hour for 5 minutes and one in 1945 that attained a rate of 6.84 inches per hour for 5 minutes. The occurrence of very high intensity rainfall at the beginning and near the end of the period thus provided a basis for checking the effects of natural revegetation on stabilizing the soil.

Aspen sites with an understory of herbs and a virtually complete mantle of litter on the ground surface yielded an average of less than .5 percent runoff, the maximum being 1.7 percent. These plots lost no measurable quantity of soil.

Annual weed plots that were located near clumps of aspen produced as much as 40 percent runoff and up to 100 cubic feet of soil per acre per storm in 1936. There has been a gradual invasion of these sites by aspen. The effects of this encroachment on runoff and erosion were noticeable as early as 1937 and have since then become more pronounced. Since 1941, for example, there has been less than 8 percent runoff, even during exceptionally intensive rains in 1945, and no soil has been moved from the plots. Thus, soil stability appears to have been achieved through natural regeneration of an aspen cover.

Other equally depleted weedy sites, too far away to be invaded by aspen, produced as much and in some cases more, runoff during storms in 1945 as in 1936. Soil losses during major storms, however, decreased from about 162 cubic feet per acre in 1936 to about 45 cubic feet per acre per storm in 1945. Thus, natural revegetation mostly by weak annual herbs, over an 11-year period, though it resulted in a substantial slowing of soil losses, was not effective in controlling storm runoff or in stopping accelerated erosion.

In 1947, all aspen was removed from one of the aspen plots, leaving the herbaceous understory and litter mantle intact. On another aspen plot, all aspen was removed and the herbaceous cover and litter mantle destroyed by fire. Two weedy plots that had shown but little recovery during the previous 11 years were also burned to deplete them to about their nearly denuded condition in 1936. Two other similar weedy plots were mulched with straw and sown to grass. Other weedy plots which were being invaded by aspen were not treated.

There have been 10 runoff-producing storms on the area since the plots were treated early in the summer of 1947. The most intense rainfall during this period occurred on September 17 and 19, 1948 when a rate of 3.60 inches per hour was registered during the maximum 5-minute period. Though the treated plots in two years have been subjected to rains of only slightly more than one-half the intensity of those prior to treatment their behavior is noteworthy.

Untreated aspen sites and weed sites on which there has been substantial increase in plant cover due to aspen invasion, continued to yield negligible quantities of runoff and no measurable quantities of soil. By contrast, weed plots that were denuded by fire produced up to 61 percent runoff and yielded as much as 208 cubic feet of soil per acre. Similarly denuded aspen sites produced up to 29 percent runoff and yielded up to 330 cubic feet of soil per acre.

Sites from which only the aspen trees were removed continued to provide complete control of erosion. The mulched and seeded weed plots also have lost no soil since treatment though they have yielded as much as 6.6 percent runoff. Thus straw mulching and grass seeding appear to be immediately effective in stabilizing eroding soil that is subjected to rainfall rates up to 3.60 inches per hour. Aspen sites appear to be equally effective when the trees are removed without destroying the understory of herbaceous cover and litter mantle. This plot study is to be continued to determine whether the treatments will be equally effective under the impact of more intense storms and to observe what changes occur in the plant cover and soil mantle over a period of years.

Stabilization of Granitic Soils

How to restore sufficient plant cover for effective protection on depleted and eroding soils continues to be a major problem in the granitic soils areas of the region. A study of revegetation methods on south-facing slopes of the downy chess range within the Boise River watershed was initiated last year in cooperation with the Artificial Reseeding Project. An important feature of this study is the use of a spray to kill downy chess at the height of its growth prior to seeding with perennial bunch grasses. It is believed this treatment may have the dual advantage of eliminating competition for moisture and of providing a natural mulch on the soil surface. The study also includes a test of fertilizers and of seeding methods. Successfully established grass stands will be tested with an infiltrometer to evaluate their effectiveness for preventing erosion during summer storms.

PLANT RELATIONS

Plant cover, in addition to its roles of keeping soil stable and of controlling potentially destructive overland flow, also plays two important parts in conditioning the amount and timeliness of seepage flow runoff. Plants intercept precipitation and thereby directly reduce the amount of water that is available for stream flow. Plants also transpire water and this withdrawal of moisture from the soil mantle creates a storage deficit that must be recharged before seepage flow can occur. Any reduction in either of these two types of losses should result in more seepage flow runoff.

Evapo-transpiration Losses

Aspen and Herbaceous Plant Cover

Additional records of evapo-transpiration losses from aspen-herbaceous, herbaceous, and bare sites were obtained last year at the Wasatch Research Center. These losses were determined by adding net summer precipitation (precipitation minus surface runoff) to the storage deficit in the soil mantle at the end of the growing season. The average annual consumptive use of water in inches from the three types of sites for the years 1947 and 1948 are as follows:

Sites	Bare	Herbaceous	Aspen
Summer precipitation	9.20	8.16	7.62
Less runoff	.46	.04	.02
Net precipitation	8.74	8.12	7.60
Soil moisture deficit	3.65	7.43	10.60
Total consumptive use	12.39	15.55	18.20

These records show that the aspen sites consumed 2.65 inches more water than the herbaceous sites from which the aspen cover had been removed, and 5.81 inches more water than the sites from which all plant cover had been removed. The differences in the consumptive losses between the sites was due mainly to a greater withdrawal of moisture from the soil mantle by the aspen plants. On the bare sites soil moisture remained at close to field capacity all season at depths of from 2 to 6 feet below the surface. On the herbaceous sites, moisture was drawn out mostly from the 0- to 4-foot depth. On the aspen sites, moisture was withdrawn from the entire profile to a depth of 6 feet.

The soil moisture deficit at the end of the growing season was 3.17 inches greater on the aspen areas than on the herbaceous sites from which the aspen had been removed. The deficit on the herbaceous sites was in turn 3.78 inches greater than on the completely denuded sites. This means that the bare sites should yield about 7 inches more water and the herbaceous sites about 3 inches more water in the spring season than the aspen areas.

Complete denudation of sloping lands is unthinkable in this region because a dense ground cover of plants and litter is required for protection against floods and erosion. However, where aspen can be harvested without impairing the protection function of the understory of herbaceous plants and litter, it may be possible to increase the useful yield of water from such sites by as much as 3 inches. It is planned to continue this study for at least another year to strengthen the validity of the differences in consumptive losses thus far obtained.

Perennial Bunchgrass and Annual Weed Cover

Several years ago the question was raised as to whether perennial bunchgrass cover of a sufficiently high density to prevent accelerated erosion on the steep, granitic soils of the Boise River watershed might not utilize excessive quantities of water and thereby decrease useful stream flow. This led to a study of soil moisture on sites occupied by a dense and vigorous stand of crested wheatgrass and by a sparse and weak stand of annual herbs. The data from this study were reanalyzed last year after further information had been obtained on the volume weight characteristics of the soil.

This analysis revealed that evapo-transpiration losses from 6-foot deep soil profiles between the beginning of growth in the spring and termination of growth in the fall were 17.89 inches from crested wheatgrass sites and 19.75 inches from annual weed sites--or 1.84 inches greater loss from the latter. However, between late fall and midwinter soil moisture recharge on the annual weed sites amounted to 7.31 inches as compared to 5.93 inches on the wheatgrass sites. This difference of 1.38 inches is probably due to greater interception and evapo-transpiration losses on the wheatgrass site during the early winter regrowth season. In any event, it appears that the wheatgrass sites will require 1.38 inches more winter precipitation to bring the soil mantle to field capacity than the annual weed sites and therefore may yield that much less water in the spring. This apparently slight advantage of annual weed cover over that of crested wheat from a water yield standpoint must be balanced by the fact that sparsely covered annual weed sites erode about 2,500 times faster than sites with a dense stand of perennial grasses.

Interception

Records of interception losses in aspen and in herbaceous stands have been obtained at the Wasatch Research Center during about two dozen summer rains. These rains varied in depth from .02 inch to 1.76 inches. Aspen intercepted about 20 percent of the precipitation in rains of more than .50 inch and up to as much as 70 percent of rains of .05 inch. The herbaceous cover intercepted about 11 percent of all rains in excess of .30 inch and up to about 45 percent of the .05-inch rains.

Last year an inspection was made of the data that had been gathered from a pre-war study of snow accumulation and melting in the ponderosa pine type of southern Idaho. A sample check of these data reveals that snow depth during three winters of observation averaged about 6 inches greater in mature ponderosa pine than in open brush and grass covered sites. Water content of the snow was also consistently greater in the virgin pine than in the open, the differences tending to increase toward the end of the melting season. In one year, on April 15, when there was only .5 inch of water in the snow on open areas there was 1.50 inches of water in the snow under the pine forest; in another year on the same date there was 1.5 inches of water in the open and nearly 6 inches of water in the snow under the forest.

The greater quantity of snow and water on the ground surface in the mature pine stands than in the open, grass, and shrub areas is in marked contrast with the relatively low amounts of snow that Wilm found in virgin as compared to heavily cut lodgepole pine, at the Frazer Experimental Forest in Colorado. One explanation for these differences is that even-aged lodgepole pine tends to develop a dense canopy with a high interception capacity whereas virgin mature ponderosa pine stands develop openings that favor deep accumulation of snow and slow melting rates. It is believed that further analysis of the snow data will verify these assumptions.

WATER RELATIONS

Precipitation

The characteristics of July-August thunderstorm rains on the Wasatch Experimental watersheds which were partially reported upon in the last annual report, were given further study during the past year. One phase of this effort revealed that summer storms with maximum rainfall rates in excess of 6 inches per hour for

5-minute periods can occur over as much as 5 square miles. Rainfall rates up to 4 inches per hour can occur over areas as large as 25 square miles, and rates of 2 inches per hour can occur over areas in excess of 30 square miles. Another phase of this study revealed rainfall rates to be substantially greater on the windward slopes of the high Wasatch Mountains near Farmington than at valley stations in the northern, central, and south-central parts of Utah. It is planned to continue the rain gage network over the experimental watersheds.

A study was made of the precipitation characteristics on the west face of the Wasatch Plateau east of Ephraim, Utah, based on 15 years of records from four climatic stations located in different elevational zones. Average annual precipitation varied from 10.88 inches at elevation 5,543 feet to 32.21 inches at elevation 9,860 feet. Analysis of the data shows there is a straight line relation between precipitation and elevation; that annual precipitation increases at a rate of 4.94 inches per thousand feet of elevation. A "zone of maximum precipitation" formerly believed to occur at intermediate elevation does not exist.

Induced Snow Drifting for Water Storage

In the spring of 1947 on the top of the Wasatch Plateau east of Ephraim, Utah, it was observed that substantial drifts, formed to the lee of clumps of alpine fir, contained approximately a 2-foot depth of water at the time snow disappeared from undrifted areas, and that these drifts persisted for an additional 3 to 4 weeks after that time. These observations led to the thought that if more drifting could be induced either by snow fences or tree windbreaks, the retarded melting of the drifts would prolong spring runoff into the period when stream flow is usually insufficient to meet the needs of the valley water users.

To explore these possibilities, snow fences were constructed in the fall of 1947, and drifts induced by these fences measured in the spring of 1948. Four fences were built, each 50 feet long; two were 7 feet high, and two were 11 feet high.

The 7-foot fences caused only a negligible amount of drifting in 1948 but substantial drifts were formed behind the 11-foot fences. On April 1, average snow depth in these drifts was 93 inches compared to a 55-inch depth on an adjacent undrifted area. Water contents of the drifted and undrifted snow on this date were 38 and 18 inches, respectively. By June 1 the snow had disappeared on the undrifted areas whereas the induced drifts were still 30 inches deep and contained a water depth of 15 inches. These drifts persisted until June 12.

Stream Flow

Ephraim Creek in central Utah drains 16,360 acres of mountain lands that lie between elevations of 6,500 and 10,200 feet. These lands yielded 15,000 acre feet of runoff each year, or the equivalent of 11 inches of water per acre. Using Thornthwaite's method of interpreting precipitation and temperature data, with checks against recorded runoff from the upper part as well as from the entire watershed, it is estimated that stream flow was yielded by elevational zones as follows:

Zones		Annual runoff	
Elevation (feet)	Area (acres)	(a.f.)	(in.)
6,500-8,000	5,990	2,500	5
8,000-9,500	6,950	7,500	13
9,500-10,200	3,420	5,000	18

These figures show that 63 percent of the watershed between the elevational range 8,000-10,200 feet and embracing the aspen-fir and subalpine zones, produce 83 percent of the runoff. There was no runoff from an additional 1,000 acres of sagebrush land below 6,500 feet elevation.

Water Quality

Last year further study was made of the sediment deposits at the mouth of Bairs Canyon near Farmington, Utah. This investigation revealed that this canyon had yielded a total of 885 acre feet of sediments from the time of the Provo stage of Lake Bonneville (20,000 years ago) to the year 1912 when the first major mud-rock flow occurred from this canyon since settlement. There has been a total of 130 acre feet of material washed from this canyon during the period 1912 to 1947, when the last mud-rock flood occurred. The average annual sedimentation rate in this most recent period is about 100 times that of the longer presettlement period. These comparative rates indicate the extent to which watershed impairment can speed up degradational processes.

RANGE MANAGEMENT RESEARCH

Range management research at the Intermountain Station is divided into four comprehensive fields: Summer Range, Spring-Fall Range, Winter Range, and Big Game-Livestock Range. Although this subdivision carries with it the implication of complete coverage, the fact is that many serious gaps exist. Scarcity of funds and the obligation to maintain certain experimental facilities have largely confined research effort on summer and winter ranges to central Utah, on big game-livestock range relationships to the State of Utah, and on spring-fall ranges to southeastern Idaho. Little or no range management research is being carried on by the Station in the State of Nevada, in southwestern Idaho, or in southwestern Wyoming.

The gaps in summer range studies are particularly serious. Lands used for summer range, most of which lie within the national forests, are important for the water they yield as stream flow, so vital to the Intermountain West. Management of grazing on these lands is particularly difficult because differences in slope, local climate, soil parent material, etc., give rise to complex patterns of many rather small vegetal associations, as compared with the extensive, few, and relatively homogeneous associations of desert and semidesert lowlands. Furthermore, management is complicated by corresponding variations in erosion hazard on mountain range land and by the fact that accelerated erosion on many sites, once it is well advanced, is hard to stop. While certain general principles have been worked out by research, their application is strongly affected by local conditions, due to the diversity of mountain range land. A greatly stepped-up research program is needed.

National forest administrators are asking for information to assist in solving practical management problems. They want to know the productive potential for specific types of range, what degree of cover and what vegetal composition to aim for in management. They want to know how specific ranges should be classified as to condition, what the indicators of trend are on these ranges, and how to read them. They want to know how much forage utilization is permissible, and what plants to use as key species in judgment of utilization. They want to know--still for specific types of range; a general rule won't do--how to tell when erosion is normal and when it is accelerated. They want to know what the effects of rodents are on the range, and how to tell utilization by deer and elk from utilization by sheep and cattle. Information of this kind and on the scale needed requires ecological research far beyond our present power to supply.

Some information is available for the subalpine and aspen zones in central Utah, chiefly on limestone soils. Practically nothing is known about range ecology in these broad types elsewhere in the Intermountain region. The same is true of mountain brush, pinyon-juniper, ponderosa pine, Douglas-fir, and lodgepole pine types, in which virtually no ecological work has been done to date. Of these the mountain brush type is probably most extensive, most complex, and most important in national-forest range management.

A specific problem that bears only in part upon summer ranges, and more generally on lower-lying spring-fall ranges, is that of cheatgrass. Two very good statements of the cheatgrass problem have recently been published (Hull and Pechanec, JOURNAL OF FORESTRY - August, 1947; Stewart and Hull, ECOLOGY - January, 1949), describing the ecology of cheatgrass so far as it is now known, and the merits and faults of cheatgrass in land management. It is necessary here only to stress the fact that, aided by fire, cheatgrass is dominating more and more territory every year, particularly in southern Idaho. Its area is not decreasing, but increasing, and with repeated fires its dominance over native vegetation--perennial grasses, herbs, shrubs, and trees--becomes more and more absolute. Spreading from abandoned dry farms, it has swept in the wake of fires, and as precursor of even more frequent fires, over vast areas of sagebrush-grass range, up into the foothills, superseding mountain brush (and thus limiting game winter range in places) and pushing timber back up the slopes. To all intents and purposes, the spread of cheatgrass is irreversible. Whatever its merits, cheatgrass is tinder for another fire, and because it thus destroys vegetation other than itself, its spread is an ecological catastrophe.

This situation calls for aggressive research on a wide front. It is important to learn how to manage cheatgrass for livestock grazing, so as to get the most out of it, for even though we were able to stop its advance today, we still would have to live with cheatgrass a long time. It is important to learn how to reseed into cheatgrass so as to get perennial vegetation in its place. It is important to learn how to control cheatgrass with grazing, fire, chemicals, and smut. But more immediately important than these needs, is the need for an ecological attack on the advancing cheatgrass front. Here, by observational study in a wide variety of conditions where cheatgrass is actually in the process of overwhelming native vegetation, it may be possible to devise means of halting its advance.

The problem is not simply one of a replacement of perennial forage species by an annual, with a question as to whether this is advantageous to the livestock operator. It is, rather, a problem affecting multiple land use, in which watershed, timber, game, and recreational values are also at stake; and there is not much question but that, from this over-all viewpoint, cheatgrass is undesirable and something needs to be done about it. What needs to be done is one of the most urgent problems that management research should attack.

Here, then, are two problems, the cheatgrass problem rather specific, the problem of managing mountain range lands much broader, including within it many specific problems. To each an ecological approach is applicable. But to attack either, without jettisoning going studies, more manpower in management research at this Station is necessary.

SUMMER RANGE

Something of the importance of summer range in the Intermountain region, and deficiencies in our research attack upon summer range have been suggested. The actual status of summer range research has not been made clear, however. Summer range work began at the Great Basin Branch Station near Ephraim, Utah, about 1911, and we are still following changes in vegetation here on permanent plots that were established in 1913. Most summer range work has been confined to this locality, and because of progress we have made and the advantages of detailed records that go back many years, it is essential that these studies be continued.

Relations between weather and plant growth, and variations in climate with topography, have received attention almost from the first (Sampson and Malmsten, Grazing Periods and Forage Production on the National Forests, U. S. Dept. Agr. Bull. No. 1405, 1926; Price and Evans, Climate of the West Front of the Wasatch Plateau, Mo. Weath. Rev. 65:291-301, 1937; Costello and Price, Weather and Plant-Development Data as Determinants of Grazing Periods on Mountain Range, U. S. Dept. Agr. Tech. Bull. No. 686, 1939). Studies of the role of microclimate in range rehabilitation, one phase of which will be described in this report (Ellison, Establishment of Vegetation on Depleted Subalpine Range as Influenced by Microenvironment, Ecol. Monog., April, 1949), are a recent development of this interest in relations between climate and plant growth. At the present time also a manuscript is in course of preparation, in cooperation with the Division of Watershed Management Research, redefining the precipitation pattern on the west front of the Wasatch Plateau (Lull and Ellison, Precipitation in Relation to Altitude in Central Utah). The highlights of this paper are given in the watershed section of this annual report.

Certain intensive autecological and physiological studies have had to be discontinued because of lack of manpower and more pressing needs in summer-range management. These include extensive phenological observations, some of which were reported in Tech. Bull. No. 686, studies of the seed habits of native species (Griswold, Effect of Alternate Moistening and Drying on the Germination of Seeds of Western Range Plants, Bot. Gaz. 98:243-269, 1936), and studies of food march and carbohydrate storage in forage plants (McCarty, The Relation of Growth to the Varying Carbohydrate Content of Mountain Brome, U. S. Dept. Agr. Tech. Bull. No. 598, 1938; McCarty and Price, Growth and Carbohydrate Content of Important Mountain Forage Plants in Central Utah as Affected by Clipping and Grazing, U. S. Dept. Agr. Tech. Bull. No. 818, 1942).

A start was made in research on management of mountain brush range between 1922 and 1925 (Forsling and Storm, The Utilization of Browse Forage as Summer Range for Cattle in Southwestern Utah, U. S. Dept. Agr. Circ. No. 62, 1929), but this work was discontinued. Permanent plots in the mountain brush zone in Ephraim Canyon have been charted periodically, however. Whenever we can tackle the problems of this zone, a widespread series of administrative study plots, some of which have been established many years, will be available for use. As has already been indicated, the mountain brush type is of very great extent in the Intermountain region, is badly depleted, and needs ecological study to answer numerous questions being raised by range managers.

A beginning has been made in studying the ecology of the aspen type. Highlights of the results of this study were given in last year's annual report. They are being organized for mimeographed publication as a Station Research Paper on judgment of range condition in the aspen type. The suitability of the criteria presented will be further tested in the field during 1949, and an effort will be made to develop more quantitative criteria partly through reexamination of old established study plots.

Subalpine range land has received more attention than any other type in central Utah, chiefly because of conflicts between grazing and watershed uses in the subalpine zone. Several of the studies already mentioned relate more or less directly to this zone. Here also synecological research and development of indicators of range condition and trend have been pushed most aggressively. The first publication of this sort appeared in 1919 (Sampson, Plant Sucession in Relation to Range Management, U. S. Dept. Agr. Bull. 791). As described in last year's annual report, the concepts presented by Sampson have been modified by more recent research aimed at reconstructing the character of original subalpine vegetation and the alterations it has undergone by grazing use. This manuscript (Ellison, Subalpine Vegetation of the Wasatch Plateau, Utah) is to be revised for publication. During the past year it has been fortified by further studies on soil profiles in relation to vegetal types, and by recharting of 36 permanent quadrats last charted in 1943.

A study of indicators for judging subalpine range condition and trend, begun by Ellison and Croft in 1942, resulted in Research Paper No. 6 written in 1944. The manuscript, greatly revised, is now titled, "Indicators of Condition and Trend on High Range-Watersheds of the Intermountain Region" and is virtually complete. This study, together with fundamental research, has emphasized the great difficulty in predicting trend accurately. Judgment of trend is more important in management than judgment of condition, and so an effort will be made during 1949 to discover new indicators of trend, if possible, by studying soil and vegetation in the field, in the light of recorded changes as given by permanent plots.

Microclimate and Range Recovery

In the subalpine zone of the Wasatch Plateau permanent plot records show that soil surfaces which are essentially bare of perennial vegetation may persist in that condition for many years. At the same time adjacent surfaces covered with a growth of dense, rhizomatous vegetation, particularly Penstemon rydbergii, maintain their identity, and under some conditions change very little in appearance, over similarly long periods. A corollary of this observation is that new plants of other species tend for the most part to become established within the Penstemon patches (or patches of other rhizmatous species), not in the bare spaces where, for soil protection, they are most needed.

There are several possible reasons why seedling plants should invade established vegetation rather than bare spaces. Among these reasons are greater disturbance of openings by trampling of livestock, erosion, burrowing of pocket gophers, and frost heaving, and on the other hand, a better soil in the protection of vegetal masses, and a greater retention of wind-blown seeds and fruits there. Several bits of evidence pointed toward the possibility that an unfavorable microclimate (particularly excessive heating and drying) limited seedling survival in the bare openings, but it was difficult to prove from this evidence whether microclimatic or soil differences were limiting.

To eliminate soil differences, plantings of Agropyron trachycaulum were made on bare, eroded surfaces, half of which were shaded artificially and half unshaded, using a paired plot design. Coarse cotton netting which reduced light intensity about 25 percent was held 6 inches off the ground by wooden frames. Such plantings were made on a number of sites between 1944 and 1947. The 1947 plantings were made in mid-June on two sites. Five pairs of plots, shaded and unshaded, were planted on each site by two men. Each man planted 100 grains of Agropyron on a portion of each plot. The plots were kept weeded and were examined four times during the year, the last examination being October 8. Although the early part of the summer was dry, frequent rain fell during late August and throughout September. The following data are numbers of surviving seedlings, in the fall of 1947, from 1,000 shaded and 1,000 unshaded grains planted by each man:

Man	Shaded	Unshaded	Total
G	358	68	426
W	501	165	666
Total	859	233	1,092

There is a marked difference in response to treatments, survival under shade being 3.7 times as great as in the open. Consistency of differences between the 10 pairs of plots is such that t = 4.06, P = .002. This result corroborates results in earlier experiments.

There is also a marked difference in response to men: W's success was half again as great as G's, and the difference is consistent within individual plots and pairs of plots. A 3-way analysis of variance with 39 degrees of freedom and with all but "treatment x man" interaction variances pooled as an estimate of error, gave very high F-values ($P < .01$) for "treatments" and "men." Differences between sites were not significant.

This experiment and others corroborate extensive observation, elsewhere on western mountain range lands as well as in the subalpine zone of the Wasatch Plateau, indicating the necessity for a favorable microclimate in order to have successful natural revegetation. The presence of bare patches alternating with patches of vegetation should be a warning that a very unfavorable environment exists. It is a condition over which the vegetation is able to exert scant control. Corrective management can take many forms, depending upon circumstances. The range manager may effect a different season of use, a shorter season of use, or lighter use, or he may eliminate grazing altogether, but in any case his objective will be to permit established vegetation to grow sufficiently tall and to leave a sufficient residue of litter so that vegetal control may be extended into the environment of the interspaces.

BIG GAME, LIVESTOCK, AND RANGE RELATIONSHIPS

A Cooperative Research Program

Studies of big game, livestock, and range relationships have been in progress for almost 2-1/2 years in cooperation with the Utah State Fish and Game Department, Utah State Agricultural College and Experiment Station, U. S. Fish and Wildlife Service, and Bureau of Land Management.

Analysis of the big game-livestock range problem in Utah has been completed and an over-all cooperative research program formulated. This program which includes work by all cooperating agencies, provides for close correlation of all phases of study. A cooperative bulletin depicting the big game-livestock range problem has been nearly completed in manuscript form with plans for publication by the State Fish and Game Department.

Preliminary studies have been made to determine methods and to select study areas where plant and animal research might be carried on jointly with cooperating agencies. Priority has been placed on study of food habit relationships of big game and livestock to determine the nature and extent of competition. Intensive studies are now under way on this problem. Incidental to these studies, data on forage composition and utilization are also being collected which will contribute to the solution of the important problems of carrying capacity and indicators of game range condition.

Studies thus far indicate that big game, livestock, and range relationships are complex and highly variable. While considerable information is at hand which can be used to improve management there is still much basic information to be secured as a basis for proper management of big game-livestock ranges.

Plans for 1949

In view of the unusually severe winter of 1948-49, special efforts will be made to get a true picture of what happens to deer and range during and following extreme winter stress. As the winter progresses forage and deer conditions on overpopulated, overgrazed range will be compared with those on range believed to be properly stocked and in good condition. Surveys of winter mortality and range condition will be made on study areas in late March and early April.

Studies on big game-livestock food habits will be continued with incidental studies on carrying capacity and indicators of game range condition.

Plans are under way for publishing the cooperative bulletin on the big game-livestock range problem in Utah.

Deer Food Habits Study

Observation of deer food habits were made on four vegetal types, three of which (aspen, spruce-fir, and sage-snowberry) were located in high summer range and the fourth (oak-sage) in intermediate spring-fall range. Utilization of grass was insignificant except in the oak-sage type where it amounted to approximately one-half of the spring diet. *Poa fendleriana*, *Oryzopsis hymenoides*, and *Agropyron spicatum* were the most prominent grasses in the diet.

In the spruce-fir type, browse made up four-fifths of the diet whereas in all other types forbs accounted for from one-third to one-half of the total forage taken. Species that made up a large part of the deer diet were *Populus tremuloides*, *Rosa* sp., *Salix* sp., *Symphoricarpos* sp., *Prunus virginiana*, *Cornus stolonifera*, *Taraxacum officinale*, *Castilleja* sp., *Viguiera multiflora*, *Lupinus* sp., *Penstemon* sp., *Stellaria jamesiana*, and *Lathyrus* sp.

Eighty percent of the total diet in each type consisted of ten species or fewer.

Deer-sheep Food Habit Studies

Utilization studies in four vegetal types on a summer sheep range show a close relationship between deer and sheep diets throughout the summer. The following tables show the plants in each type eaten by both sheep and deer, their relative abundance, the extent to which each was utilized by both classes of animal and the importance of each in the diets of the two animals. Deer and sheep use were separated by making one observation just prior to the time the sheep grazed a type and another after they left it. Species making up less than 1 percent of the diet of either class of animal are not included.

Species	Aspen type				Spruce-fir type			
	Percent of total herbage	Total weighted percent utilization	Percent diet		Percent of total herbage	Total weighted percent utilization	Percent diet	
			Deer	Sheep			Deer	Sheep
Populus tremuloides	14	52	60	22	40	13	27	48
Mahonia repens					7	4	3	2
Osmorhiza occidentalis	Trace	62	2	1				
Ligusticum sp.	1	74	7	3				
Trifolium sp.					12	20	35	3
Taraxacum officinale	3	61	5	5				
Aster spp.	3	40	10	4	2	10	2	2
Phacelia sp.	1	36	2	1				
Penstemon sp.					1	29	5	1
Carex sp.					5	18	3	9
Bromus anomalus					3	22	1	8
Totals	22	54 av.	86	36[1]	70	16 av.	76	73
	Sage-snowberry type				Currant-snowberry type			
Ribes sp.					9	14	1	2
Symphoricarpos oreophilus					11	10	6	4
Aster spp.	Trace	68	9	2				
Mertensia ciliata					13	84	50	43
Phacelia sp.	Trace	69	4	3				
Castilleja sp.	Trace	37	5	1				
Lupinus sp.	1	32	69	3				
Penstemon sp.	Trace	49	2	2	4	11	5	2
Stipa lettermani	2	47	8	9	23	10	1	9
Agropyron sp.					10	21	3	8
Totals	3	50 av.	97	20[2]	70	25 av.	66	68

---

[1] Remainder of diet consisted of approximately 1/3 *Mertensia* and 1/3 *Carex* and grasses.

[2] Remainder of diet consisted of approximately 1/2 browse (mostly *Ribes* and *Symphoricarpos*) and 1/3 grasses.

In each type, six or seven species made up two-thirds or more of the deer diet. These same species, in the spruce-fir and currant-snowberry types, also made up two-thirds or more of the sheep diet. Obviously then the probability of competition is great and if one class of animal were removed, the grazing capacity of the range for the other would be materially increased. On the other hand, in the aspen and sage-snowberry types the species that accounted for nearly all of the deer diet made up only one-third or less of the sheep diet. Under these conditions, the probability of competition is small and the removal of one class of animal would not greatly affect the grazing capacity of the range for the other. It is significant then, that the likelihood of competition between two or more classes of animals may vary considerably with vegetal type.

The place of grasses in the diets of deer and sheep, on the areas observed, is indicated by the fact that they made up only 8 percent or less of the deer diet whereas they accounted for 20 percent or more of the sheep diet in each type.

Deer-cattle Food Habit Studies

Studies of deer-cattle range on the Fishlake, Wasatch, and Uinta National Forests show that grass makes up the bulk of cattle summer diet while deer eat chiefly browse and forbs. The small amount of grass grazed by deer is taken early when grass is tender. The following table shows class of forage available, amount used and percentage of diet for deer and cattle:

Forage consumption by deer and cattle

	Grass and sedges			Forbs			Browse		
	Lbs./A available	Lbs./A used	Percent diet	Lbs./A available	Lbs./A used	Percent diet	Lbs./A available	Lbs./A used	Percent diet
				Aspen summer range (6 areas)					
Deer	241	2	4	121	30	57	242	21	39
Cattle	241	59	88	121	5	7	242	3	5
				Browse summer range (2 areas)					
Deer	141	0	0	161	25	17.6	301	117	82.4
Cattle	141	89	68.5	161	13	10.0	301	28	21.5

The aspen areas were grazed lightly to moderately by cattle and lightly to heavily by deer the past year. There was but little overlap in class of forage used by deer and cattle.

On the browse types there was somewhat greater overlapping in deer and cattle use of forbs and browse than on aspen range. This was apparently due to heavier grazing by cattle, a shortage of the more palatable grasses and presence of more palatable shrubs--especially bitterbrush.

Heavy grazing intensified the overlap in deer and cattle forage use. However, even under moderate to light use there were certain species utilized by both, i. e., bitterbrush (*Purshia tridentata*), serviceberry (*Amelanchier alnifolia*), milkvetch (*Astragalus* spp.), and clover (*Trifolium* spp.). **Aspen not a reliable "key species" on deer range.**

Proper use of aspen is often considered an index to proper use of deer range in Utah and adjoining states. Studies of deer use at cattle exclosures on the Wasatch and Uinta National Forests show that when other forage is available aspen does not rank as a choice forage species. The following figures compare utilization of aspen with utilization of some of the more palatable forage plants on four aspen areas grazed lightly to moderately by deer:

	Aspen	Amelanchier	Rosa	Prunus	Geranium	Aster
Average percent use	6	20	23	19	45	24

In central and southern Utah aspen is often browsed severely where deer populations are high. Under lighter use, however, several species of browse and forbs are more highly preferred by deer than aspen.

Highlining and close cropping of aspen is easily recognized by the public and is a good indicator of heavy overuse by deer. However, aspen utilization does not appear to be a sensitive guide to proper stocking.

Forbs important as indicators of summer deer range condition

Forbs make up a large percentage of the deer diet on most summer range types studied. Several species also show high preference ratings. Studies in deer-cattle exclosures on the Fishlake National Forest show definite changes in vegetation which further bring out the importance of forbs as range condition indicators. The following shows the major changes on totally protected plots compared to plots grazed by deer but protected from livestock since 1932.

Location and grazing class	Average volume weight--Lbs./acre				
	Gentian	Senecio	Potentilla	Aspen	Grasses & sedges
Big Flat:					
Total protection	13.2	25.2	9.2	103.5	29.1
Grazed by deer	1.4	0.5	0.9	9.7	94.5
	Aster	Helianthella	Potentilla	Aspen	Grasses & sedges
Grindstone Flat:					
Total protection	26.5	13.0	8.0	67.3	86.1
Grazed by deer	4.8	Trace	4.0	16.2	131.4

The smaller volume of grasses and sedges on totally protected areas is believed to be due to competition with aspen reproduction and possibly also with forbs. All evidence points to the need of greater consideration of forbs in the management of deer range.

SPRING-FALL RANGE

Spring-fall ranges of southern Idaho are mainly sagebrush-grass, originally dominated by bluebunch wheatgrass (Agropyron spicatum) and big sagebrush (Artemisia tridentata) but supporting a variety of other grasses, herbs, and shrubs. Today they are generally badly depleted because of trailing and overstocking. Livestock first became established on the Snake River plains about 1860 and by 1882 the range was showing signs of overstocking. For the next 30 years the range was heavily grazed by resident herds while trailing continued. According to Colonel E. N. Wentworth in his book "America's Sheep Trails," sheep were used to reduce the amount of sagebrush on certain lands in southwestern Idaho. This could mean nothing but extreme range abuse, and continued use has not allowed for recovery of the range since that time.

Studies of spring-fall ranges of southern Idaho were begun at the U. S. Sheep Experiment Station in 1923. Heavy grazing in either early or late spring has been shown to be detrimental, and moderate grazing at the same time each spring is likely to be. Heavy grazing, on the other hand, is not particularly harmful to grasses and herbs but rather destructive to shrubs, probably because shrubs store most of their reserve foods in the twigs, and thus lose their reserves when the twigs are grazed. Grasses and herbs are very susceptible to damage by herbage removal from about May 25 to June 10 in most years. Rotation of grazing during this spring period or even complete deferment until fall is advisable. (Craddock and Forsling, The Influence of Climate and Grazing on Spring-Fall Ranges in Southern Idaho, U. S. Dept. Agr. Tech. Bull. No. 600, 1938; Blaisdell and Pechanec, Effects of Herbage Removal at Various Dates on Vigor of Bluebunch Wheatgrass and Arrowleaf Balsamroot, ECOLOGY, 1949.)

Weather causes great annual variation in forage production. Following a single year of severe drought, native vegetation may require 5 to 7 years to recover to predrought density. Forage production may fluctuate as much as 60 percent above or below normal and similar stages of plant development may vary as much as 40 days from one year to another. Forage utilization should be based on 60 to 75 percent of normal forage production. Close utilization of forage plants in early spring is not detrimental if such grazing is not repeated year after year. Grazing may begin when bluebunch wheatgrass reaches a height of 2-1/2 inches.

In the field of sampling technique and methodology the spring-fall range project has developed the weight estimate method. It is useful for determining forage utilization and production on experimental pastures and ranges. Although personal error of estimates may be greater than more exact methods such as clipping, efficiency of sampling sagebrush-grass type ranges is much enhanced by the greater number of plots observed.

Since 1900, cheatgrass has been spreading on deteriorated ranges in southern Idaho. A partial analysis of the cheatgrass problem has been made, indicating its values and its dangers, how it compares with perennials in forage production, soil-holding ability, dependability, forage value, season or use, etc.

In 1941, a grazing intensity study was begun under a rotation plan, as an interim study until plans could be formulated for something more comprehensive. Because of the war this interim study has been continued for eight years. One heavily and one lightly stocked pasture were inventoried in 1947 as a pilot study and reported in the 1947 annual report. This test indicated significant differences in vegetation due to rate of stocking. Inventories of all the pastures are to be made in 1949.

Controlled burning has proved to be a cheap and effective method of removing big sagebrush. Where a good understory of herbaceous vegetation exists, deferment from grazing for at least a year, and light to moderate grazing thereafter, will give the herbaceous vegetation a chance to become firmly reestablished and will retard reinvasion by sagebrush. Where a good understory is lacking, artificial seeding is necessary following the burn, and similar precautions regarding grazing are necessary. (Pechanec and Stewart, Sagebrush Burning--Good and Bad, U. S. Dept. Agr. Farm.Bull. No. 1948, 1944.) Some ranges are not suited to burning because of the danger involved or the lack of proper fuel, so the brush must be eradicated mechanically--by plowing, railing, using a pipe harrow, etc. These operations must often be followed by reseeding (Pechanec, Plummer, Robertson, and Hull, Eradicating Big Sagebrush, Research Paper No. 10, 1944.)

Benefits of Burning Last More Than 15 Years

In 1948, 12 and 15 years after burning, experimental burns at the Sheep Station and in Fremont County were resurveyed to determine longtime effects of burning on forage production and to measure rates of reinvasion of sagebrush and bitterbrush. Compilation and analysis of these data are not complete except for numbers of sagebrush and bitterbrush plants on the Fremont County burn.

Sagebrush plants were classified in one of four classes described in the table below. Although some plants became established every year following the burn, large numbers of sagebrush plants became established in 1939 and 1944. Plants classified in the table as not well established are those originating in 1944 or later; those well established but not producing flowerstalks are of mixed 1939 and 1944 origin, and those well established and producing flowerstalks are mostly 1939 plants. The table compares the number of sagebrush plants per 100 square foot burned plot with those on similar unburned plots. Burned plots, of course, have no unburned plants.

		Class of sagebrush plants		
Treatment	Unburned	Well established, producing flowerstalks	Well established, no flowerstalks	Not well established
Unburned plots	7.89	1.17	3.68	0.50
Burned plots	----	1.95	3.72	1.07

On the average, the burned plots, after 15 years, have enough plants to repopulate the area with sagebrush almost as completely as the unburned plots are now populated with old plants. Nevertheless, these new plants are smaller than the old plants; they do not dominate the range after 15 years, and most of the forage produced is available to grazing animals. Another interesting fact is that the unburned plots also are supporting rather large numbers of plants established since the burn.

These burned plots were classified according to distance to the nearest source of sagebrush seed, to determine the effect on reproduction, but no correlation is evident between numbers of new plants and distance from seed source.

On the burn there are still rather large areas where sagebrush was entirely eliminated and has not reinvaded. Such areas are generally on better sites where soils are deep and herbaceous cover is dense. Herbaceous competition on these sites seems too severe for establishment of sagebrush. In its stead, there are numerous bitterbrush plants. Whereas sagebrush seed is light and scattered by wind, bitterbrush seed is large and is usually planted by rodents. Perhaps because of this planting, bitterbrush seedlings become established more readily than sagebrush seedlings in dense herbaceous vegetation.

Bitterbrush is not especially resistant to fire, but if bushes are not too severely burned they may sprout. On the Fremont County burn, bitterbrush is abundant, even on unburned plots. An average of 0.64 plant per 100-square foot burned plot appeared in 1948 to have been sprouts. In addition, there are 3.28 bushes per plot which have originated from seed since the area was burned. In contrast to this, unburned plots have an average of 1.06 bushes per 100 square feet. Bitterbrush plants on the burn are uneven-aged indicating establishment of some plants each year. From these data it appears that bitterbrush, a valuable species on spring-fall ranges may actually increase as a result of burning, given sufficient time and a source of seed for new plants. Because experience in other places has shown bitterbrush to suffer severely from fire, particularly from repeated burning, this conclusion is of limited application.

Heavy Spring Grazing and Sheep Weights

In the 1947 annual report, for the first time, differences in sheep weights were reported between heavy and light rates of stocking. Again in 1948, ewe weights were significantly different between grazing treatments, although lamb weights were not (see table).

Item	Stocking rate		
	14 sheep days per acre	18 sheep days per acre	22 sheep days per acre
No. of ewes	33	80	59
No. of lambs	33	80	59
Av. wt. change per ewe, lb.	-8.58	-12.85	-13.33
Av. fleece wt. per ewe, lb.	10.51	10.20	10.19
Av. change body wt. per ewe, lb.	+1.93	- 2.65*	- 3.14**
Av. gain per lamb, lb.	31.00	29.70	29.77
Net gain, ewes plus lambs, lb.	+32.93	+27.15	+26.63

*Significantly different from 14 system at 5 percent level.
**Significantly different from 14 system at 1 percent level.

Sheep grazed the pastures from April 26 to June 14 in 1948. A series of four pastures was grazed by each group of sheep, under a rotation plan, each pasture for 12 to 15 days. Lambs averaged about 10 days old when they were put on the pasture.

Ewes lost weight on the average, during this 8-week grazing period. All were nursing young lambs and, in addition, an average of slightly more than 10 pounds of wool was shorn from each ewe. Including weight of wool, ewes on lightly stocked range (14 sheep days per acre) actually gained 1.93 pounds while those on moderately (18 sheep days per acre) and heavily stocked range (22 sheep days per acre) lost 2.65 and 3.14 pounds, respectively. Weight of ewes on moderately and heavily stocked ranges was not significantly different. Lambs on lightly stocked range average 1.30 and 1.23 pounds more gain, respectively, than those on moderately and heavily stocked range. Although these differences are not significant statistically, they parallel differences measured in 1947.

Vegetation and soil of the heavily stocked range have shown evidence of deterioration rather clearly for several years. Establishment of many young sagebrush plants in openings is an especially good indicator of this deterioration, and evidences of loss in vigor by desirable forage plants, and of accelerated soil erosion, point in the same direction. Differences in ewe weights are less sensitive indicators, for they have not shown up clearly until the last couple of years, and differences in lamb weights are still less sensitive as indicators.

WINTER RANGE

The 65,000,000 acres of winter range are located in the drier portions of the Intermountain region where annual rainfall averages from 5 to 10 inches and snowfall is usually light enough to permit winter grazing. The major units of winter range lie in great blocks, often several million acres in size, mostly far from spring-fall and summer ranges. They support 4 to 5 million sheep and approximately 250,000 cattle for 4 to 6 months each year.

Surveys in 1931-32 revealed that forage production on many winter ranges had been reduced more than 50 percent through overgrazing. On vast areas many of the better forage species had been killed or severely reduced, and undesirable plants such as little rabbitbrush, shadscale, Russianthistle, and cheatgrass had invaded.

In 1933 the Desert Branch Station was established to provide scientific information for formulating sound management and proper use of winter range. Studies were initiated on utilization, grazing capacity, herbage yields, plant growth, and watering livestock; and sheep and wool weights were measured to determine the effects of management practices on sheep, wool, and lamb production. A manuscript on these studies has been submitted for publication as a departmental circular, "Management of Winter Sheep Ranges in the Intermountain Region." An article, "Drive the Water to the Sheep" was published in 1946 in the NATIONAL WOOL GROWER.

Pasture studies to determine effects of light, moderate, and heavy grazing on winter range vegetation have been carried on for 14 years (1935-47). Total herbage production on the lightly, moderately, and heavily grazed pastures in 1947 was 100, 75, and 63 percent greater than in 1935. Much of the increase in total herbage came as a result of favorable precipitation in 1947, but the increase was relatively greater on pastures lightly and moderately grazed. The low ebb in production occurred in 1943 following two years of low precipitation. Decrease during these years was most marked in heavily grazed pastures. Changes in plant cover and herbage production, already well marked, are still in progress and indications are that subsequent changes, especially those on moderately grazed and totally protected areas, are tending toward more shrub and less grass cover. If these trends are substantiated they will be important in determining the type of management and proper degree of grazing best suited to winter range.

Forage Utilization on Moderately Stocked Winter Range

The degree to which any forage plant is utilized depends on several factors, the most important being: (1) the plant's palatability, (2) season of use, (3) associated species and their abundance, and (4) rate of stocking. On moderately used range in good condition palatability and season of use have the greatest influence. In a number of cases, season of use affects palatability: winterfat and bud sagebrush are taken most readily in spring when they begin to show a little green. Some of the effects of season on palatability is shown in the following table:

Utilization of winter-range forage plants through a 40-day grazing period, 1939

Species	Utilization by 10-day intervals Jan. 5-14	 Jan. 15-24	 Jan. 25-Feb. 3	 Feb. 4-13	 Total
	Percent	Percent	Percent	Percent	Percent
Globemallow	45	30	5	5	85
Black sagebrush	40	30	10	0	80
Indian ricegrass	35	30	5	5	75
Bud sagebrush	5	10	40	15	70
Winterfat	10	10	15	25	60
Galleta	10	10	5	30	55
Sand dropseed	0	5	5	15	25
Shadscale	5	5	10	5	25

Utilization measurements made during four consecutive 10-day periods in 1939 show that the most palatable species such as globemallow, Indian ricegrass, and black sagebrush were almost completely utilized during the first two periods. Bud sagebrush, also a very desirable species, received practically no use until the third period, toward late winter when the buds begin to slip and turn green. In the first two 10-day periods sheep ate only relatively small amounts of moderately palatable or less desirable species. During the last two 10-day periods, utilization of these species greatly increased. Type of weather and condition of the plants at time of grazing frequently alter utilization during any given year. When snow is moist and available sheep utilize greater quantities of dry grasses than during dry periods.

When a range has been utilized to the maximum while still allowing for perpetuation and increase of the more desirable species, it is said to be properly utilized. When plants of high value such as black sagebrush and Indian ricegrass are properly utilized, snakeweed, Russianthistle, and other less desirable plants show light use. By estimating the percent of the plant that has been used on what is considered to be a properly grazed range, a proper use factor can be established. Thus, when winterfat has been grazed to 55 percent, only 10 percent utilization has occurred on snakeweed. Overgrazing will frequently kill the most desirable species and injure many of the moderately palatable ones. Average utilization for some of the more common plants at the Desert Range Station are shown in the following table. These were determined from moderately grazed pastures during the nine seasons 1937-38 through 1945-46.

Average herbage utilization on moderately grazed pastures 1937-38 to 1945-46

	Percent		Percent
Grasses		Shrubs	
Indian ricegrass	75	Bud sagebrush	50
Galleta	50	Winterfat	55
Sand dropseed	25	Fourwing saltbush	40
Spike dropseed	20	Fringed sagebrush	35
Blue grama	10	Shadscale	20
		Nevada ephedra	10
Forbs or "weeds"		Snakeweed	10
		Small rabbitbrush	10
Globemallow	80	Rubber rabbitbrush	10
Pepperweed	25		
Russianthistle	10		

RESEARCH IN RANGE RESEEDING

During 1948 in the range reseeding division, tests of the suitability of species were continued, investigations of methods of seeding and reducing competition went forward, and the studies of the influence of site factors in getting grass stands and producing forage were advanced. The higher returns and better quality of forage from selected strains repeated the indications of previous years, and the determination of results on grass and cattle from studies on grazing reseeded ranges was prosecuted even more carefully than in previous years. A special study on airplane pellet seeding was undertaken in cooperation with the range management division of the Regional office. This is the first report on this undertaking, thus it is given in some detail. Other phases of research work, together with future programs, are reported under the following headings: Species suitability, methods of seeding and removing competition, site factors, plant breeding and strain studies, and grazing studies of reseeded ranges.

AIRPLANE PELLET SEEDING

For three years, public attention has been called to airplane pellet seeding of range lands. Large areas were seeded by this method on the Papago and Navajo Indian reservations in Arizona and New Mexico and last year on Bureau of Land Management ranges in Wyoming, Idaho, and Oregon. Unsatisfactory stands of grass resulting from these seedings have been attributed by some to the inadequacy of the method and by others to extremely unfavorable conditions or to uncontrolled grazing after seeding.

To clarify the possibilities of range betterment by means of airplane pellet seeding, a study of the method was begun during 1948 on the Kigalia Ranger District of the LaSal Division of the Uinta National Forest. The Regional office financed the seeding that it might be used as a guide in a possible action program. The Experiment Station cooperated in planning experimental procedures, aided in getting the seeding done according to plan and in establishing control plots, in checking the work as done, and in making laboratory germination tests of pelletized and unpelletized seeds.

Description of Area

The area seeded lies between 6,400 and 8,400 feet elevation and includes four vegetational zones: (1) pinyon-juniper, 6,400 to 6,900 feet (1,070 acres); (2) mountain brush including much sagebrush, 6,900 to 7,700 feet (5,200 acres); (3) open ponderosa pine, 7,700 to 8,100 feet (1,210 acres); and (4) aspen, 8,200 to 8,400 feet (190 acres). The hillsides are comparatively gentle with gradients mostly of 5 to 20 percent with a few slopes of small area up to 40 percent. The soil is in moderately good condition. Precipitation is generally favorable to plant growth. Native grasses and other desirable forage, once abundant on this range, have been depleted until forage production nowhere exceeds 100 pounds per acre air-dry weight.

Procedure

In the four cover types, airplane seeding was done at the rates of one pellet per square foot (60 pounds to the acre) and two pellets per square foot (120 pounds to the acre), and with naked seed at approximately 10 pounds to the acre. Seven forage species were used, some in one cover type and some in another. Each pellet contained only a single species, and the pellets were mixed to give the desired combination of species for each zone. The naked seed was sown as a mixture. Species used were crested wheatgrass, bulbous bluegrass, orchardgrass, slender wheatgrass, smooth brome, timothy, and yellow sweetclover. Crested wheatgrass predominated in the mixture in the pinyon-juniper cover and orchardgrass in other cover types.

In addition to the three methods of seeding by airplane, a number of ground treatments were made at four selected locations. These included harrowing, plowing, and railing after seeding and burning of brush before seeding. Portions of each of these study sites were fenced. Comparisons will be made of the effectiveness of the various combinations of methods used as well as of the effects of grazing on fenced and unfenced areas.

Program, 1949

To complete the LaSal pellet seeding study, the relative success of pellet seeding and seeding by recommended ground practices will be compared and evaluated. By means of a large number of plots along transect lines, the number and distribution of plants by species will be recorded for each treatment. This will be done for 1949, 1950, and 1951 when a report will be prepared. Yield data for the various treatments will be taken as soon as the seeded species are well established. Data on the amount and time of precipitation will be collected at eight places on the area. Arrangements have been made to protect the area from grazing through 1951, but some unavoidable drifting of livestock into the area is expected. Observations will also be made on the amount of disturbance of litter and soil under each treatment.

The fenced and unfenced areas will be studied by means of 20 plots for each treatment. The fenced plots will be protected from all grazing except where deer invade by jumping fences. The data from numerous study plots will permit rather close comparisons between different seeding methods.

SPECIES SUITABILITY

Current Activity and Results

In the course of 15 years a few more than 400 species have been tested in duplicate nursery 3-row blocks on cultivated and weeded land. Species showing promise in the nursery were subjected to tests in quadruplicate range plots (12' x 36') where competition was reduced by several treatments for a few years. After that no weeding or cultivating was done; each species had to hold its own against weeds and other invaders. From the range plots, species were selected for "pilot" plantings, and the best of these for "action" seeding under one site condition or another.

By this means a list of recommended species for the different precipitation-vegetation zones was determined for the Intermountain region. Elevation insofar as it influences temperature is also a factor in the make-up of environmental conditions for which species are adapted. Coolness as well as precipitation favor the perennial grasses suited to Intermountain conditions.

The table below lists the species for the several zones, presents the most highly recommended species first, followed by those less highly recommended in descending order. A few newly tried species are not recommended as highly in some instances as they may deserve and in others perhaps somewhat too highly. Until a larger fund of knowledge is acquired regarding potentialities of newly tried species, their exact place in a series cannot be given accurately.

The species at the head of each zonal list are outstanding for reliability in that zone. The species lowest in the list need to be investigated more fully by extending their trials longer until more years give a climatic cross section. The backlog of information on how they respond needs to be widened to a greater variety in kind of site. For example, it is now shown that four new species--Agropyron intermedium, A. trichophorum, A. elongatum, and Elymus junceus--are not nearly so well adapted to the really severe drought areas as is Agropyron cristatum. In the next two more favorable zones, upper sagebrush and mountain brush zones, they do remarkably well.

Forage species adapted for range reseeding in various zones of the Intermountain Region, arranged in order of reliability.

I. LOWLANDS

Vegetation: Sagebrush, Russianthistle, cheatgrass, and pinyon-juniper

A. Precipitation 8-13 inches

Species	Recommendation
1. Agropyron cristatum	General in region. Plant alone.
2. Poa bulbosa	Limited to mild winter area of southwest Idaho and for rough terrain in other parts

B. Precipitation 13-18 inches

Species	Recommendation
1. Agropyron cristatum	General use in region
2. A. intermedium	" " " "
3. A. trichophorum	" " " "
4. A. elongatum	" " " "
5. Elymus junceus	" " " "
6. Agropyron spicatum and inerme	Better drained sites in foothills
7. Poa ampla	" " " " "
8. Agropyron smithii	Heavier soils or in swales
9. Elymus condensatus	" " " "
10. Medicago sativa	Deep soils, best sites only

C. Moist alkali lands with moderate salt content

Vegetation: Saltgrass and sparse greasewood

Species	Recommendation
1. Agropyron elongatum	General in region
2. Elymus junceus	Drier parts and low water table
3. Festuca elatior arundinacea	Salt land that receives some supplemental water
4. Melilotus officinalis	
5. Kochia scoparia	Productive annuals on former crop land, abandoned because of too much soil salt
6. Bassia hyssopifolia	

Table Continued

II. MOUNTAIN LANDS

A. Mountain brush. Precipitation 18 to 30 inches.

Vegetation: Brush in aspen and timber openings

Species	Recommendation
1. Bromus inermis	General in region. General except on dry slopes. Grow well in shade of high stature brush.
2. Arrhenatherum elatius	
3. Agropyron subsecundum	
4. Bromus carinatus	
5. Elymus glaucus	
6. Agropyron trachycaulum	
7. Dactylis glomerata	
8. Agropyron intermedium	General except in shade of high stature brush.
9. A. trichophorum	
10. A. elongatum	
11. A. smithii	
12. Elymus condensatus	
13. E. junceus	
14. Agropyron cristatum	Restricted to dry, south-facing slopes.
15. A. spicatum-inerme	
16. Poa ampla	
17. Medicago sativa	Restricted to better soil types when there is no or little shade.
18. Astragalus cicer	
19. Astragalus falcatus	
20. Lotus corniculatus	
21. Melilotus officinalis	

B. Subalpine zone. Precipitation above 20 inches.

Vegetation: Weedy flats, penstemon, dandelion, tarweed

1. Bromus inermis	General use from dry to moist sites.
2. Arrenatherum elatius	
3. Bromus carinatus	
4. Agropyron trachycaulum	
5. Bromus erectus	
6. B. tomentellus	
7. Astragalus cicer	
8. Viguiera multiflora	
9. Phelum pratense	Restricted to the more moist sites.
10. Poa pratense	
11. Heracleum lanatum	
12. Osmorhiza occidentalis	

Program, 1949

It is proposed to strengthen studies of species suitability and to fill in the gaps in the data regarding responses of all species to various zones and sites by the following steps:

1. Taking data for a few years on current plantings of recently studied species.

2. Making new trials at a few of the less favorable sites not as yet properly included in past studies. In many cases not enough seed was at first available to make a complete set of studies to give all information needed.

3. Making more plantings in the high mountains (subalpine zone) where only a few of the sites have been adequately studied.

4. Collecting the most drought-resistant species obtainable and studying their responses on the semidesert salt-shrub ranges.

5. Testing mixtures of species for seeding in order to determine the degree to which mixtures improve forage stands, production, or grazing utilization.

6. Providing adequate studies of the suitability of strains of species are more fully presented in "Strain Studies."

METHODS OF SEEDING AND REMOVING COMPETITION

Years of investigations by this Station indicate that competition from native vegetation on an area must be greatly lessened in order to permit seeded species to establish themselves. Except under aspen and deciduous brush with a heavy leaf fall, no stand worth consideration has been obtained without reducing competition from natural cover. Consequently, broadcasting seeds by hand or by airplane, unless there is heavy leaf covering, is practically wasted effort so far as our tests show.

The principal types of vegetation that must be removed in order to reduce competition are sagebrush, cheatgrass, pinyon-juniper, mountain brush, subalpine perennial and annual weeds, and salt-desert shrub. As explained in the Annual Report for 1947, priorities were set up in early years for working first in the sagebrush type, and later in the mountain brush, subalpine, salt-desert shrub, and pinyon-juniper as part of the desert type. Burning, various mechanical means, and the last year 2,4-D have been used for brush removal.

Sagebrush Competition

One study, begun in 1940, was designed to measure the effects of seeding grasses 1 and 2 years before sagebrush was seeded, simultaneously with sagebrush, and 1, 2, and 3 years after sagebrush seeding. Plot averages in 1948 showed that grass yields were much larger than sagebrush on plots seeded to grass prior to or as late as 1 year after sagebrush, but sagebrush yields were larger than grass on plots seeded to grass 2 or 3 years after sagebrush as indicated by the following table.

Average air-dry herbage yields of sagebrush sown on individual plots and of a grass mixture seeded on the same plots at various times in relation to the sagebrush

2 yrs before		1 yr before		same yr as		1 yr after		2 yrs after		3 yrs after	
Grass	Sage	Grass	Sage	Grass	Sage	Grass	Sage	Grass	Sage	Grass	Sage
1,164	29	1,141	85	858	460	778	369	486	750	392	724

Other studies, begun as early as 1937, provided for seeding crested wheatgrass into 2-, 3-, 4-, and 5-year-old stands of sagebrush and for concurrent establishment of several reseeded grasses and sagebrush seedlings. Seeding into 2- and 3-year-old stands of sagebrush produced stands of crested wheatgrass which rated "good" or "very good," whereas comparable seedings into 4- and 5-year-old stands of sagebrush produced only "poor" or "fair" stands of wheatgrass. Crested wheatgrass had little effect on the sagebrush seedlings. Concurrent establishment of several grasses and sagebrush gave an initial advantage to the grasses. As the sagebrush plants became larger, however, they competed with the grasses and caused a reduction in grass vigor, density, and yield on many plots.

Sagebrush seedlings apparently compete keenly with reseeded grasses and may prevent establishment of successful reseeded stands. The older and denser the stand of sagebrush seedlings and the drier the site, the less chance there is for successful reseeding. Also, good stands of reseeded grasses established prior to the introduction of sagebrush into the stand suppress subsequent sagebrush seedlings or entirely prevent sagebrush invasion for an indefinite period. For these reasons, reseeding depleted sagebrush-grass ranges during the same year as sagebrush destruction by fire or mechanical means will provide maximum opportunity for sagebrush control and will give the reseeded species maximum opportunity for success.

Use of 2,4-D

The most recent method studied was spraying with 2,4-D solution. The commercial preparation known as "Weedone" has been the principal carrier of 2,4-D used in the 1947-48 studies at the Intermountain

Station. Preliminary hand spray applications had shown that it would kill sagebrush and rabbitbrush and not injure grass noticeably. Since many seeded stands of grass bore from little to much rabbitbrush or sagebrush or both, 2,4-D spray was studied as a means of removing the brush from the grass and also of killing brush in native stands.

Spray was applied in August 1947 with a power sprayer used by Summit County for spraying farm weeds. Weedone was used on an experimental area on the Wasatch Forest near Kamas, Utah, at the rate of 1 gallon in 100 gallons of water and 1 in 60 gallons to treat separate plots, with an untreated check plot between. Another plot was treated with the county spray material designated as 2,4-33. The Weedone sprays were also applied to native stands of mixed sagebrush and rabbitbrush. A heavy rain fell before the 2,4-33 spray was dry, but after the others had fully dried.

In October 1947 the current growth sprayed plots seemed to be killed, except for the 2,4-33 treatment which showed little injury to brush. By August 1948, 94 and 95 percent of the sagebrush plants and 88 and 90 percent of rabbitbrush plants were dead from the two Weedone sprays but none on the 2,4-33 plot, which apparently had been washed off by the rain. The few snowberry plants in the Weedone plots were killed, 67 and 90 percent, respectively. Rosebush was practically uninjured and grass not at all.

From a purely biological point of view, it is clear that 2,4-D will kill sagebrush and rabbitbrush. No noticeable injury to grass occurred whereas spraying to eradicate these two native stands killed the shrubs. It seems feasible to kill these shrubs in stands of grass. Dead plants of thick stands, most of them waist high, would still have to be removed before seeding would be practical. Our experimental costs of spraying were around $10 an acre for plots. Undoubtedly commercial methods would reduce the cost.

Mechanical Methods of Removing Sagebrush

As previously reported, the wheatland plow has been the most effective of the mechanical methods, removing 60 to 80 percent of the sagebrush. The self-clearing pipe harrow can with care remove 40 to 60 percent on certain sites, and the rail drags 30 to 50 percent. The improved Brushland plow, built by the Forest Service equipment laboratory under the direction of the Equipment Committee and tested at the reseeding school held on the Minidoka National Forest, removed 85 to 90 percent of the sagebrush. It seemed unusually effective. Because of a stump-jump feature it can be used on land much more rocky than can the wheatland plow. Its more thorough eradication and greater ability to work in rocky ground makes it very promising in the Intermountain region.

Juniper and Mountain Brush

So far, methods of eradication in oakbrush, chokecherry, and pinyon-juniper have been to plow the sagebrush openings or to burn the taller brush and woodland cover. Good grass production has followed seeding in these vegetal zones when the plants are killed. No mechanical means of removing these larger treelike forms of brush have been found.

Cheatgrass Eradication

Cheatgrass has been reduced to less than 5 percent of a stand by burning soon after the seeds are ripe, after which drilling usually produces good stands of reseeded grass. Early disking or shallow plowing before seeds are developed followed by drilling has also been successful. Deep-furrow lister drills have made seeding directly in cheatgrass stands possible. Broadcasting in undisturbed cheatgrass has failed, and seeding with ordinary drills has brought only mediocre results.

Reducing Competition in the Subalpine Zone

In the subalpine zone studies in eradication were begun only 2 or 3 years ago. It was found that the wheatland plow and the pipe harrow were not effective in dandelion or tarweed. These weeds have since been plowed out with a moldboard plow and it looks as if both dandelion and tarweed can thus be satisfactorily eradicated. Tarweed plants were successfully removed by fall treatments with wheatland plows and pipe harrows. The following year, however, produced a full stand of the annual tarweed that smothered out the grass. Later studies show that spring or summer treatment before seeds are formed will largely eradicate tarweed, after which good stands of grass may be obtained. For example, in Farmington Canyon on the Wasatch Forest, spring-tooth harrowing in June followed by immediate seeding gave unusually good stands of grass with merely a trace of tarweed.

Applications of 2,4-D both as Weedone (acid) spray and salt spray killed tarweed, but left knotweed uninjured and this plant competed very strongly with grass seedlings.

Methods and Time of Seeding

Studies in methods of seeding showed that in years with favorable precipitation conditions, broadcasting at plowing time as reported last year for Ruby Valley, Nevada gave as good stands as drilling. This year's data at Dinner Station, Nevada show that in a year with unfavorable precipitation, drilling gave more than twice as good a stand (rating 5.7) as broadcasting at plowing time (rating 2.7).

Time of seeding data still favor later fall seeding for lowlands. When summer rains are fairly frequent, as in parts of the mountainous areas, spring or early summer seeding is often satisfactory. Of the last 5 years, 3 have been favorable in spring seeding because of timely summer precipitation. Where summer rains cannot be depended on, fall has proved to be the safest time to seed in the Intermountain region.

Status of Research

Based on research findings, a vigorous and successful "action" program is going forward on sagebrush ranges where *Artemisia tridentata* is the cover species. Within this zone, rabbitbrush cover is much harder to control. More study is needed in eradicating rabbitbrush and other species of sagebrush as *A. cana* and *A. tripartita.* The methods suited for *A. tridentata* are also in need of careful revision when used on mixed sagebrush-greasewood and greasewood stands. Lower-cost methods of eradicating sagebrush are continually sought for. The costs of mechanical eradication and reseeding in 1948 were around $8 an acre, which is rather high. One of the great virtues of burning sagebrush is the low cost of only 30 to 40 cents an acre, indicating the fact that burning needs to be used more fully, with necessary precautions to prevent escape of the fire.

Mechanical or chemical methods of removing oakbrush, chokecherry, maple, and pinyon-juniper are badly needed. Bulldozers can be used effectively but the cost is excessive. A thorough study of 2,4-D and its derivatives, and of other chemicals is urgently needed.

Program, 1949

The program of research on methods for the next 2 or 3 years will include the following:

1. Determination of methods of eradicating *Artemisia cana* and *tripartita*, rabbitbrush, and greasewood. The search for low-cost methods will be continued.

2. Determination of the best mechanical treatments for eradicating tarweed, wyethia, and dandelion. A search will be made for mechanical methods of eradicating oakbrush, chokecherry, and scrub maple.

3. Organization, so far as funds permit, of studies in the use of chemicals for eradicating oakbrush, chokecherry, and scrub maple, as well as of such weedy species as tarweed, wyethia, and dandelion.

4. Study of the problem of killing pinyon-juniper.

5. Continuation of the study of methods of seeding ranges covered with cheatgrass.

SITE FACTORS

Current Activities and Results

The success of any range reseeding is the result of several ecological variables. The factors which may be readily observed and measured are precipitation, temperature, soil, and native vegetation. A study of site quality factors is now under way to determine the degree of correlation that exists between these variables and the eventual yield of grass, or other forage, from a given site. An attempt is being made to establish a few criteria which are readily observable but which are sufficiently reliable to permit a high degree of accuracy in determining the potentialities of a given site.

Successful reseeding has been done in areas having as little as 8 inches of precipitation where temperatures and soils were favorable. The arid perimeter of the sagebrush zone has about these qualities, except where the soil is too gravelly or sandy. In dry valley areas, high soil salinity is often encountered but does not ordinarily occur on land covered with sagebrush. For reseeding, precipitation of 12 to 16 inches is more advantageous and 16 to 24 inches is extremely favorable.

Many of the grasses that are suitable for reseeding do not thrive under the higher temperatures that exist in the lower valleys even though precipitation may equal that of higher elevations. In this class are smooth brome, orchardgrass, tall oatgrass, and to some degree, crested wheatgrass.

Success in establishing a stand on a reseeding site is not influenced by elevation as a separate site factor. High elevations are, however, correlated both with cooler temperatures and more precipitation in the Intermountain region. These factors directly affect the production of grasses.

Deep, well-granulated soils containing enough organic matter to absorb and retain good supplies of available moisture through long periods of dry weather are especially favorable to high production of range forage. When precipitation, temperature, and soils all improve with changes in elevation then herbage yields usually increase noticeably. In Ephraim Canyon this condition prevails in three sites used for plot tests--Sorenson Field, Majors Flat, and Station headquarters. The still higher site at the summit decreased in yielding capacity, most likely due to less favorable soil conditions, shorter growing season, and greater drainage of the soil moisture, as shown in the following table:

Yields of herbage in 1947 for 9 forage species used in reseeding at four sites in Ephraim Canyon, Manti National Forest, Utah. In the first table the figures are actual yields in pounds per acre, the second shows relative yields when the average for each site is assigned the figure 100.

Species	Sorenson Field	Majors Flat	Station Head-quarters	Summit Enclosure
	Actual yields			
Crested wheatgrass	3,040	3,685	2,545	2,500
Intermediate wheatgrass	2,540	6,165	16,250	4,550
Stiffhair wheatgrass	1,575	6,650	11,537	1,000
Slender wheatgrass	1,245	3,575	3,650	2,402
Tall oatgrass	1,225	2,750	5,037	8,750
Smooth brome	987	5,275	9,540	5,450
Western wheatgrass	750	3,625	9,125	1,100
Mountain brome	300	2,725	3,460	1,760
Alfalfa	4,112	8,025	640	2,750
Average	1,753	4,720	6,865	3,362
	Relative yields			
Crested wheatgrass	173	78	37	74
Intermediate wheatgrass	145	131	237	135
Stiffhair wheatgrass	90	141	168	30
Slender wheatgrass	71	76	53	71
Tall oatgrass	70	58	73	260
Smooth brome	56	112	139	162
Western wheatgrass	43	77	133	33
Mountain brome	17	58	50	52
Alfalfa	235	170	93	82
Average	100	100	100	100
Elevation (feet)	5,500	7,200	8,950	10,200
Precipitation (inches)	12	18	29	26

The table shows not only tremendous differences in total yields of herbage but also that the four sites are not by any means equally favorable to all species. The exposed situation and thinner soil mantle at the summit make for a more arid site than at the two intermediate elevations. A high water table at Station headquarters is highly favorable to several grasses but nearly fatal to alfalfa. Sorenson Field is too warm and arid for intermediate, stiffhair, and slender wheatgrasses and for smooth and mountain bromes.

Status of Research

Within the sagebrush zone the relation of precipitation, temperature, soil, and vegetal cover are known well enough to permit recommendations for action seeding. In the mountain brush and aspen zone much general information is available but needs to be filled in and strengthened by continued research. In the higher mountains, research has just begun as to the relation of length of growing season, snowbank areas, and soil type. This whole field needs to be studied vigorously and intensively. On desert areas the precipitation limits for successful seeding need to be determined. Likewise the relative promise of seeding on sandy and heavy soils, on loose granitic soils, and on saline soils needs to be investigated.

Program, 1949

During 1949 and the next 3 or 4 years the following program will be undertaken:

1. Studies which were initiated in 1947 in the sagebrush zone with crested wheatgrass will be continued and expanded. These studies to determine the capability of soils as revealed by observable soil characteristics, plant cover, and erosion conditions will be extended to the high mountain lands. These are principally high value watershed lands, many of them so damaged as to need reseeding.

2. Extreme soil types will be studied more carefully to determine how to establish reseeded stands and to maintain them thereafter. Among the extreme soil types are the loose granitic soils of central Idaho, the heavy clays and loose sands of central and southern Utah and Nevada, the badly eroded soils of some flood source areas, and the salty soils of desert bottom lands. Studies have been begun on several of these soils but need to be strengthened and continued.

3. Careful and somewhat comprehensive fertilizer tests are needed soil type by soil type. A few studies are planned on soils of the phosphate deficient areas on Colorado River drainages and the badly eroded soils on flood source areas.

PLANT BREEDING AND STRAIN STUDIES

Current Activities and Results

The plant-breeding line project is composed of two distinct phases. The first phase is the production of strains of forage species by means of controlled pollination. This part is conducted at Logan, Utah by Dr. Wesley Keller of the BPISAE. We cooperate by keeping him informed about our needs and advise with him on how he can help us. The second phase is investigating the value of strains whether obtained as a result of controlled pollination, geographic isolation, or selection. This is part of the work done at the Intermountain Station.

Approximately 200 strains are under test at Majors Flat Nursery. Smooth and mountain bromes, slender, western, crested, and spiked wheatgrasses, blue wildrye, and orchardgrass are the species represented in the strains. The strains show great variations in yield, palatability, longevity, and winter hardiness. Some strains of species are 3 to 5 times better than other strains, and the better ones are much superior to the stock species. Many details about strains were included in the 1946 report and repetition seems unnecessary.

Status of Research

In keeping with findings for cultivated crops, it seems likely that all forage species when subjected to breeding will yield strains superior to the unselected stock of the species. This breeding work is a long, tedious, and costly operation. It should be started on a comprehensive basis for all species used in seeding. The job, however, if fully done will entail a cost far beyond the small expenditures now available for that purpose. So far this has been an incidental phase of reseeding investigations. It seems inevitable, however, that within a few years it should exceed and perhaps largely supplant the work on suitability of stock species for range reseeding.

Program, 1949

1. Continue to acquire superior strains from any source available. These will be added to those under observation in our nursery and in range seedings.

2. A comprehensive search for geographic and selected strains should be undertaken and more support given to adequate testing of strains derived from controlled pollination.

GRAZING STUDIES ON CRESTED WHEATGRASS RANGE

Grazing studies consist principally of methods of grazing by cattle at Benmore and one on sheep grazing at Ephraim.

Cattle-Benmore

As described in the 1947 report, the 24 experimental pastures grazed uniformly in 1947 were grazed according to differential treatments in 1948. In cooperation with the Utah Agricultural Experiment Station and the Soil Conservation Service, the 24 pastures were divided into two blocks, each of 12 pastures, stratified somewhat according to grazing capacity. Treatments included four methods of grazing and three intensities in each block, making a full replication in addition to hidden replication. The treatments are as follows:

All spring	Light,	Moderate,	Heavy
Spring rotation	"	"	"
10 days deferred	"	"	"
10 days off end	"	"	"

Intensity of grazing is based on the degree of utilization of the forage, being 50, 65, and 80 percent utilization, for light, moderate, and heavy grazing, respectively. The numbers of animals were varied to bring about the desired degree of use. This was accomplished very closely, 49.8, 63.5, and 78.3 percent for the three intensities in block I and 49.2, 61.3, and 75.5 in block II. Hereafter, with experience it can undoubtedly be achieved even more closely in block II. The approximation of the actual use to the desired in block I was as close as could be hoped for.

The forage inventory and utilization survey was made by major species with the result shown in the following table:

Production of air-dry forage per acre and percent utilization by species for light, moderate, and heavy grazing, Benmore, 1948.

Species	Light		Moderate		Heavy	
	Lbs./A	% Util.	Lbs./A	% Util.	Lbs./A	% Util.
Crested wheatgrass	440.1	49.5	493.6	62.4	475.7	76.9
Cheatgrass	31.4	14.1	29.3	15.4	23.1	29.8
Western wheatgrass	13.0	30.3	3.9	27.4	10.2	47.5
Bulbous bluegrass	11.1	4.5	7.4	8.8	5.4	15.4
Weeds	9.6	12.4	4.8	18.4	2.0	38.7

Small areas of cheatgrass are being replaced by crested wheatgrass, but western wheatgrass and bulbous bluegrass show no signs of being replaced. In spite of the dry spring, the production of crested wheatgrass increased somewhat over 1947, which had a wetter spring. It is not yet clear whether the proportion of rabbitbrush and sagebrush plants in the grass stands is being affected by grazing.

Cattle weight gains indicate even in the first year some effects of intensity of utilization of forage but calf weight gains do not even suggest differential effects. Average gains are shown in the following table:

Cattle and calf gains at Benmore, spring 1948.

Treatment	Pounds gain per day	
	Over 6 months	Calves
Light grazing--8 pastures	2.80	1.78
Moderate grazing--8 pastures	2.84	1.92
Heavy grazing--8 pastures	2.41	1.93
All spring grazing--6 pastures	2.50	1.88
Rotation--6 pastures	2.57	1.79
10 days deferred--6 pastures	2.67	1.80
10 days off end--6 pastures	2.92	2.05
Over-all average	2.67	1.88

These gains come from 511 cattle and 197 calves weighed individually when put in and taken out of the pastures. They were subjected to 12-hour shrink in each case. Moreover, these gains of around 2-1/2 pounds per day have repeated themselves for four consecutive spring grazing periods of about 65 days each.

Status of Research

The Benmore grazing study constitutes a well-planned, practical-sized operation yielding valuable data. It is measuring the effects of intensity of grazing, and comparing four methods of grazing.

Sheep-Ephraim

The study with sheep at Ephraim is largely exploratory in its nature. Its results suggest the need for a more complete study of the grazing use of reseeded range by sheep. Many evidences point to the probability that crested wheatgrass in particular can withstand severe use for a period provided it is allowed to recuperate afterward. Under a planned system of management this faculty might prove a valuable asset. At any rate it is subject to corroboration or refutation.

Much more information is needed concerning the response of both livestock and vegetation to various methods, time, and intensities of grazing use. It would be highly desirable to have a body of knowledge on the grazing of mixed stands in comparison with stands of single species. The work under present study does not cover this phase of the problem. Nor does it cover the relative ability of the several species to be grazed by different methods, intensities, and stages of development. Much yet remains to be done.

Program, 1949

For 1949 and the next 2 or 3 years the program for grazing studies of reseeded range is as follows:

1. Continue studies on the Benmore cattle grazing study according to plan.

2. Continue the small sheep grazing study at Ephraim.

3. Gather further observational data on grazing practices and results from cooperating stockmen at various localities throughout the region.

WHAT MAY BE EXPECTED FROM RANGE RESEEDING?

For a number of years Federal agencies and stockmen have been seeding range land on a considerable scale. Not counting pellet seeding which is too new to have proved or disproved itself, the Forest Service has seeded in the Intermountain region by proved methods around 200,000 acres of forest range. The Soil Conservation Service has seeded by careful procedure many thousands of acres, the Production and Marketing Administration has cooperated with ranchers in important range seeding, and the Bureau of Land Management has been pushing vigorously a reseeding program. All told, there has been seeded in Utah approximately 500,000 acres. In Idaho about 400,000 acres, largely through Production and Marketing Administration cooperation, have been seeded. The part of Wyoming in the Intermountain region is now actively engaged in range reseeding and Nevada is just beginning to develop this means of range betterment.

Results which may be expected in the way of grazing from seeding ranges are illustrated by a few large-scale seedings in each of Idaho, Nevada, and Utah.

Forage production from 14 large-scale seedings at various sites in Idaho, Nevada, and Utah. Data collected in 1948.

		Elevation (ft.)	Precipitation (in.)	Acres	Cow months per a.
	IDAHO				
Boise Nat. Forest	Willow Creek	4,000	16	800	0.80
Private	Orchard		14	1,200	0.3*
	(*Overgrazed--protected enclosure yielded 610 lbs./A.)				
Boise Nat. Forest	Cottonwood			50	0.8
Bur. Land Mgt.	Raft River	5,000	12	80	0.9
	NEVADA				
Bur. Land Mgt., Stockmen and Humboldt Nat. Forest	Ruby Valley	6,200	15	815	0.6
Bur. Land Mgt., Stockmen and Humboldt Nat. Forest	Dinner Station	5,500	11	90	0.5
Humboldt Nat. Forest	Buttermilk	5,000	9	132	0.3
	UTAH				
Manti Nat. Forest	Dusterberg Ridge	8,500	26	45	1.9
Manti Nat. Forest	Willow Creek	8,300	26	70	1.8
Private	Ephraim	5,500	11	40	0.7
Private	Ephraim	6,000	12	80	0.8
LaSal Nat. Forest	Dry Mesa	8,100	20	1,000	0.8
LaSal Nat. Forest	Nielson Pasture	8,500	23	400	0.9
LaSal Nat. Forest	Joshua Flat	8,400	23	80	0.9

FLOOD CONTROL SURVEYS

General Organization

The organization and staffing of the flood control survey group was continued through 1948 on about the same basis as existed at the close of 1947.

Early in the year Vincent Twoomey was transferred from R-2 to head up the watershed appraisal work, a position vacated late in 1947 by the transfer of Kenneth Taylor to the Guayule Research project. Two training positions, one each in hydrology and land use, were filled by the transfer of Merle Tigerman and George Carlson from assistant ranger positions in R-2.

M. E. Baudendistel, who had headed up the land use work, transferred in June to the newly created flood control survey unit at the Northern Rocky Mountain Station. His position has not yet been filled. Clayton N. Weaver, District Ranger on the Roosevelt National Forest, was obtained on a loan basis from R-2 to assist on the Missouri River Basin survey and was assigned as the Forest Service representative on SCS survey crews. After field work on the Missouri survey was concluded Weaver spent the remainder of the year with Forest Service crews working on the South Platte watershed.

Three student assistants were employed during the summer months as the operating crew for the infiltration tests which were made on the South Platte watershed.

Near the end of the year, J. S. Adair, Sedimentationist, transferred to the USGS. His position is not yet filled.

Planned Program, 1948

At the beginning of the year it was planned that the principal efforts of the flood control survey staff would be directed toward: (1) Completion of the Wasatch Front Survey; (2) initiation and completion of a survey of the South Platte watershed above Kersey, Colorado; (3) cooperation with the Soil Conservation Service in a survey of the middle Rio Grande; (4) initiation of a survey of the Virgin River; (5) completion of survey reports on the Fountain and Cherry Creek watershed; (6) revisions as required of the previously prepared survey reports on the Boise River and Sevier Lake watersheds; and (7) completion of a report to the Soil Conservation Service on the forest and associated range phases of the Gila River watershed.

Accomplishments, 1948

Soon after the first of the year work was started on the South Platte watershed and forested portions of the middle Rio Grande watershed although actual field work was delayed until spring because of weather conditions. This intervening time was devoted to the preparation of review drafts of the Fountain River and Cherry Creek survey reports and completion of the forestry and range phases of the Gila River survey. In addition, the final field draft of the Sevier Lake survey report was reproduced and referred to other Federal agencies for review and comment.

During the fore part of the year, an unlooked-for development which materially affected the season's work was the decision of the Department of Agriculture to begin a basin-wide flood control survey of the Missouri River Basin. At first it was planned that this survey would be completed by June of 1950 but, soon after crews were organized and field work started, a further decision was reached to complete the survey including drafting of the report by December of 1948.

The high priority attached to this survey required that it take precedence over other survey activities. Major readjustments in prior plans and personnel assignments became necessary. Concurrently the upper Missouri and Yellowstone watersheds were assigned to the Northern Rocky Mountain Experiment Station at Missoula leaving the Intermountain Station responsible for immediate survey of the South Platte above Kersey, the Laramie River watershed, and the North Platte watershed above the Pathfinder Reservoir. In addition, the Soil Conservation Service requested Forest Service assistance on the Black Hills area, the Nebraska National Forest, the shelterbelt area, and the farm woodlands of eastern and central Nebraska and Kansas.

Fortunately it was possible to complete all but about 3-man-months of the required field work on the forest lands of the Rio Grande before the Missouri River survey program developed. The remaining field work on the Rio Grande was finished in late fall after work on the Missouri River survey was completed.

At the request of the Soil Conservation Service a complete Type F infiltrometer was loaned to that agency for a period of about 3 months during which time it was used for a large number of infiltration tests of the principal soil-cover complexes on the middle Rio Grande watershed. The results obtained from a number of these tests will be useful to the Forest Service in other portions of New Mexico and in parts of Arizona and southwestern Colorado. In addition to the loan of equipment, William Murray was detailed to the Soil Conservation Service for a period of 2 weeks to train the SCS infiltration crew.

The Missouri River program did not take final form until nearly midsummer at a time when the previously planned intensive survey of the South Platte watershed was well under way and it was decided to finish the survey of this watershed in much the same manner as originally planned although the work was speeded up. Some modifications were made, such as in extent and degree of sampling as dictated by available personnel and the time limit set for completion of the Missouri River report. On the South Platte watershed it was possible to complete fairly detailed studies of essential factors. Among these were: completion of flood damage estimates, rate and extent of sedimentation, hydrologic behavior of the watershed and its principal tributaries, infiltration rates of the principal soil-cover complexes, which included the completion of 110 separate infiltration runs using two Type FA infiltrometers, mapping of soils, mapping of plant cover and erosion, and the development of a program of land treatment and structural measures for flood control. Considerable dependence was placed upon secondary sources of information. Some extension and expansion of data obtained on the South Platte watershed was possible on the Laramie River and North Platte watershed. Through consultation and advice of national forest personnel and review of Forest Service project work inventories much needed information was obtained.

Some additional personnel were obtained by detail from Region 2 of the Forest Service but in general the personnel problem was largely met by adjustment, and in some cases postponement, of earlier work plans.

The survey of the Missouri River Basin was carried out jointly by the Soil Conservation Service and the Forest Service under the leadership of the former. This required considerable time of survey personnel for consultation and other joint work at the Lincoln, Nebraska headquarters of the Soil Conservation Service.

It was originally planned that approximately 6 week's additional field work would be required to complete field phases of the Wasatch Front survey but early in the year a need developed for early completion of a survey report on this watershed. Plans were therefore revised, mostly by a reduction in the number of samples to be studied, and a field draft of the report was completed on the basis of field work previously done plus some additional data obtained from secondary sources.

Another unexpected development was the catastrophic flood on the Columbia River in the spring of 1948 which resulted in a special study by the Forest Service of this flood while it was in progress. This required approximately 3-man-months of time by flood control survey personnel.

Decision by the Department of Agriculture to prepare a complete agricultural program for the Missouri River Basin at an early date required that information on improvement measures obtained by the flood control survey be incorporated with all other estimates. This made it necessary to spend considerable time with Regional Offices of the Forest Service and with the Forest Service representatives at Lincoln assigned to this task in order to develop work outlines and in the actual collection and analysis of material.

As a result of other assignments, the initiation of a survey of the Virgin River watershed was delayed and it was not until rather late in the year that this study got under way. No field work was done but most of the preliminary phases of this job were finished. This included such things as the preparation of base maps, collection and review of data on precipitation, stream flow, flood history, flood damages, soils, and geology.

Other accomplishments include:

1. Completion of review drafts of survey reports on Fountain River and Cherry Creek watersheds. After review by other agencies, these reports were again revised to include important comments.

2. Completion of final field draft of survey report on Sevier Lake watershed.

3. Receipt of comments by other agencies on first draft of Boise River watershed survey report and preparation of the second review draft.

4. A report to the Soil Conservation Service on the forest and associated range phases of the Gila River watershed which is to be included in the survey report on that watershed.

5. A compilation was begun of published and other known information on the Colorado River Basin which will be pertinent to future flood control surveys in that basin. This also included preparation of a base map of the entire basin and the assembly of data needed for the later preparation of more detailed maps of the major subdivisions of the basin.

Problems

While some delay has occurred in preparation of final drafts of the survey reports, it is recognized that in the main this has resulted from the time required for the formulation of over-all Forest Service and Departmental procedural policies. Many of these are now rapidly shaping up and it appears that the final processing of reports will move along at an accelerated rate.

The assignment of quick surveys, encompassing one summer season of field work, of large watersheds such as was the case in the Missouri Basin survey present many problems, especially with respect to the technical sufficiency of the results. Sounder findings could no doubt be secured by material expansion of the survey staff but this consideration is undesirable from the standpoint of maintaining a closely knit, stable, and well-trained crew. If such surveys are made of other large river basins the most practical solution seems to be that of allowing several years for completion of each such survey.

Information on land use, cover, and condition and the infiltration rates of principal soil cover complexes continue to be the elements of surveying which are most time consuming and therefore most expensive. No immediate solution to this problem is suggested. As surveys progress, an increasing amount of information will become available which can be applied to other areas to be surveyed in the future. This is perhaps especially true in the case of the determination of average infiltration rates.

Considerable reliance has been placed upon project work inventories maintained by the national forest administration as a source or check of remedial measures needed on national forest lands. In numerous cases these inventories have not been adequately revised for several years. In addition, many of those prepared several years ago do not reflect the more realistic thinking which now is increasingly prevalent among Forest Service personnel concerning program needs for adequate watershed protection. It is understood that these inventories are to undergo thorough revision in the near future. If this is done, flood control surveys will be materially facilitated.

From the standpoint of organization there is a definite need to fill the sedimentationist position which is now vacant. It is also desirable to supplement the present staff by filling a training position in engineering and a similar position in hydrology.

Plans for 1949

Immediate attention will need to be given to the completion of survey investigations in the Missouri River Basin so as to facilitate the inclusion of the flood control program into the over-all agricultural program which is now being prepared for the basin. This will consist mostly of the compilation and reproduction, on a subwatershed basis, of the program measures deemed necessary for flood control purposes. It will also be necessary to separate the program measures in each of these subwatersheds according to principal classes of ownership. This will also be supplemented by maps for each of the subwatersheds illustrating the essential phases of soils, plant cover, plant cover condition and erosion, and significant hydrological data.

Although field responsibility for the preparation of the Missouri River Basin flood control survey report has been fulfilled, the results of the fairly detailed survey of the South Platte watershed will be recorded in report form for flood control survey file records and for distribution to Region 2 of the Forest Service, the Rocky Mountain Forest and Range Experiment Station, and to the Regional Office of the Soil Conservation Service. This is considered desirable so as to provide these agencies with information which may later be needed in planning and installing the recommended program.

Work on the survey of the Virgin River watershed will be stepped up and it is planned that the necessary field work will be completed during the coming summer and fall months. Much of the needed hydrological information is already assembled but the infiltration rates of certain significant soil-cover complexes will need to be ascertained by field tests. Other field studies will include those dealing with land use, soils, erosion, sedimentation, remedial program needed, and flood damages excepting the sediment deposit into Lake Mead.

The middle Rio Grande watershed now being surveyed by the Soil Conservation Service includes approximately 5,500,000 acres of forest and associated range lands. During the past year Forest Service assistance has been furnished to the Soil Conservation Service for a study of flood problems and their solution on these lands. Of early priority in 1949 will be the completion of a report to the Soil Conservation Service on these phases of the survey and assistance in the preparation of portions of the reports and appendix which pertain to Forest Service interests.

Survey investigations will be initiated during the fore part of the year on the upper Rio Grande watershed which includes that part of the Rio Grande above the mouth of the Rio Chama. At present it is planned that these preliminary studies will be confined to investigations of land use, land conditions, and needed land treatment measures. Arrangements have been completed whereby Forest Service Region 2 will contribute a limited amount of assistance to the study in the form of personnel assignments.

It is apparent that the survey staff will need to spend a significant portion of its time in the revision of reports already prepared. Included are survey reports for the Sevier Lake, Boise, Wasatch Front, and Fountain Creek watersheds. It is expected that all of these will be reproduced in final form during the year. In some cases this will entail the circulation of revised reports to other members of the FIARBC and to other interested agencies.

A preliminary approach to flood control problems in the Colorado River Basin was begun late in 1948. This will be continued and expanded. Included will be such things as: preparation of base maps for the major subwatersheds of the basin; preparation of a bibliography of known information; collection and preliminary analysis of hydrological data; assembly of published data and maps on soils, geology, and plant cover; and further analysis of problems of a research nature which will need to be at least partially answered in order that an adequate flood control program may be developed later.

Officials of Salt Lake City have indicated that they intend to start a flood control program on city-owned watershed lands and it is anticipated that some time of flood control survey personnel will be spent in assisting other members of the Station staff and representatives of the city in planning the proposed measures and in training those who will carry out the work.

FOREST MANAGEMENT RESEARCH

Accomplishments

1. Cut-over study. A report on the 1932 cut-over study of reproduction and stocking of ponderosa pine was completed early in the year and presented to Administration for review. This has revealed some worthwhile information on areas where high volumes of the original stand were removed. All these areas were logged by horses, although an additional area logged by tractor was available for comparison. Some of the more important conclusions reached in this study which dealt with areas logged from 7-26 before the examination are:

   a. No new reproduction of ponderosa pine can be expected on an area before 10 to 15 years after logging except by coincidence.

   b. Horse logging is preferable to timber extraction by tractor.

   c. Douglas-fir reproduction is liberally represented in all types and on all aspects which suggests that securing reproduction of this type presents no problem.

   d. North aspects support most reproduction, preponderantly Douglas-fir; only on south aspects is there a preponderance of ponderosa pine.

This and additional information contained in the study will prove useful in planning new methods of cutting studies.

2. Permanent sample plots. Five of the seven methods of cutting plots established in 1933 in the Experimental Forest were remeasured after 10 years of growth. In addition, a set of thinning plots on Cottonwood Creek, established in 1928 and 1929, were remeasured and rethinned. Most field work necessary to put these plots in order was also completed.

3. Release study. Measurements were taken on 88 released suppressed trees on a cut-over area and 20 comparable suppressed trees in a virgin stand to determine diameter growth 15 years before and 15 years after release and, in the case of the suppressed unreleased trees, the corresponding period. It is believed the results of this informal study will be most revealing.

4. Problem analysis. Work on a formal problem analysis of the forest management research needs of the region has progressed to where a statement covering the research program in some detail is needed to complete it.

5. Personnel. Only a negligible amount of computational work was possible due to lack of personnel. Robert W. Richman, assistant in forest management who was available from June 7, was inducted into the Army in mid-November.

Program, 1949

a. Complete problem analysis.

b. Remeasure two methods of cutting plots.

c. Complete computations and analysis of methods of cutting and thinning plots.

d. Complete analysis of release study.

e. Locate a suitable area or areas of ponderosa pine second growth for experimental cuttings and forest management in the vicinity of Idaho City. Draw up proper plans for approval.

ECONOMIC RESEARCH

World War II is now far enough in the past so that its effect on the economy and resources of the Intermountain region can be observed. The war had a more permanent influence than most people realize. New industries, particularly steel, and military establishments developed rapidly in a number of localities at the beginning of the war. In many areas this resulted in a shift from a condition of underemployment to one of labor shortages. War workers, attracted from other regions, swelled the natural rate of increase in population.

Most of these changes have extended beyond the end of the war. Many of the war industries and establishments have continued to function or have shifted to peace-time operations. Apparently many of the workers who came here during the war intend to remain. Between 1940 and 1947 the population of Utah increased at twice the average rate for the rest of the country and this trend is expected to continue. During the same period the population of Nevada increased at an even higher rate.

In spite of some dislocation of industry at the end of the war, unemployment has been remarkably low. Whether this fine record of economic expansion can continue will depend to a marked degree on how wisely the resources of the region are developed and managed. The sharp upward trend in population has placed an added drain on all the natural resources on which the economic life of the region is based. Among these resources one of the most crucial is the wild land, that is, land which has not been improved for agriculture or other uses. This land yields timber for housing and industry, forage for livestock and big game animals. It provides large areas of scenic beauty for outdoor recreation. It stores water for irrigation, water power, culinary and industrial uses, and in storing water it holds back the flood waters, rocks, and debris which might otherwise cause great damage in populated valleys. But because of past misuse, many of the wild lands of the region do not provide as much timber, forage, game, and water as they are capable of producing.

Scientists and technicians are fast learning how to manage and rehabilitate wild land so that it will produce the maximum yield of water, forage, and soil stability. But there is a gap between scientific knowledge and practical application of that knowledge. Certainly some of the reasons for this gap are economic in nature. Range land managers may know what adjustments need to be made in land use, but they do not always know how to make those adjustments with the least possible dislocation of the economy of the area. They may know what work needs to be done to rehabilitate the range, but they have no accurate method for determining what investments public and private owners are justified in putting into such work. To help fill this gap a study is being undertaken at the Intermountain Station to evaluate the position of range resources in the economy of Utah. This state has been singled out for special study because of its greater concentration of population and industry and the consequent pressure for maximum use of resources. The plan is to make a broad survey of the economy of Utah in order to determine the role which range resources play in the economic life of the state. Trends in range resources and in the livestock industry will receive more detailed attention.

A study of such broad scope must necessarily be more of a compilation and analysis of existing data than a collection of new facts. The Station does not have the funds and manpower necessary to initiate an extensive fact-finding project. Because of the breadth of the subject, which extends beyond the knowledge of any one individual, it has been proposed that the cooperation of other interested groups and agencies be sought in interpreting the facts after they have been compiled. It is hoped that an appraisal of this type will not only give the general public a clearer picture of the importance of range resources, but also aid in establishing better management of the wild land resources of the state.

This study has been emphasized here at the expense of older work because it is a new project. Other phases of economics research can be summarized more briefly. At the middle of the year Arthur H. Roth left the Station to work with the Bureau of Agricultural Economics. It is a source of some satisfaction to the Station to know that its men are in demand elsewhere. He was replaced by Dr. Henry Gilbert White, formerly with the Lake States Forest Experiment Station.

There are several lines of work on which some progress can be reported: Early in the year a range economic problem analysis was completed. In March a report entitled An Economic Analysis of Public Grazing Problems in Central Utah was released by the Station, thus bringing the central Utah area study to a close.

Work was continued on a study of the cost of reseeding range land in the Intermountain region. Figures on direct cost of reseeding public land are readily available, but indirect costs and costs of private reseeding are more difficult to obtain. Reseeding costs have risen sharply since the war, but these increases are not out of line with the general rise in level of prices. Rising costs have been offset in part by improvement in planting techniques and in greater success of planting. Any accurate appraisal of benefits to be derived from the reseeding of depleted ranges will have to await the results of present, large-scale reseeding projects.

The Station economist has also been called on to supply a wide variety of facts to aid in solving the many post-war forest and range problems of the region and nation. Some of the larger requests filled during the year included compilation of estimates of 1947 and 1948 output and value of forest products, preparation of a generalized forest-type map of the region, preparation of information and maps to be used in planning for a survey of the forest resources of the region, and pretest of the forms to be used in the 1950 Census of Agriculture. Although this type of work delays the completion of projected research, it is considered to be an important function of the Station.

PUBLICATIONS

I. Publications during the calendar year 1948

A. Departmental publications

Bailey, Reed W., G. W. Craddock, and A. R. Croft. Watershed management for summer flood control in Utah. U.S.D.A. Misc. Pub. 639.

Campbell, R. S., Lincoln Ellison, and F. G. Renner. Management that restores the range. U.S.D.A. Yearbook, 1948. pp. 221-226.

Costley, R. J., P. F. Allen, Odell Julander, and D. I. Rasmussen. Wildlife, a resource of the range. U.S.D.A. Yearbook, 1948. pp. 243-248.

Holscher, C. E., and D. A. Spencer. Sheep, goats, and grasslands. U.S.D.A. Yearbook, 1948. pp. 94-99.

Pearse, C. Kenneth, A. Perry Plummer, and D. A. Savage. Restoring the range by reseeding. U.S.D.A. Yearbook, 1948. pp. 227-233.

Price, Raymond, Kenneth W. Parker, and A. C. Hull, Jr. Improvement through reseeding. U.S.D.A. Yearbook, 1948. pp. 564-568.

Stewart, George. Grass and water keep the keys. (The mountain region). U.S.D.A. Yearbook, 1948, pp. 541-543.

______________. Pastures and natural meadows. (The mountain region). U.S.D.A. Yearbook, 1948. pp. 543-548.

B. Outside publications (in scientific and professional journals, etc.)

Bailey, Reed W. Forest and range research in Utah and the Intermountain region. UTAH, 10(9): 6-7, 24. Sept. 1948.

______________. Geologic understanding and watershed management. Proc. Inter-American Conf. on Conserv. of Renewable Natural Resources. Denver, Colo. Sept. 1948. (Processed)

______________. Reducing runoff and siltation through forest and range management. Jour. Soil and Water Conserv., 3:24-31, Jan. 1948.

Bailey, Reed W., and G. W. Craddock. Watershed management for sediment control. Proc. Fed. Interagency Sedimentation Conf., Denver, Bureau of Reclamation. Jan. 1948. (Processed.)

Craddock, George W. Insuring Utah's water supplies through watershed research. UTAH, 10(9): 14-15, 27, 29. Sept. 1948.

Croft, A. R., Water loss by stream surface evaporation and transpiration by riparian vegetation. Amer. Geophys. Union Trans., 29:235-39. April 1948.

Curtis, James D. Animals that eat ponderosa pine seed. Jour. Wildlife Management, 12:327-28. July 1948.

______________. Aspen: The utility timber crop of Utah. The Timberman, 49:56-7:116. June 1948.

______________. Aspen's place in the sun. Amer. Forests, 54:264-65:288. June 1948.

______________. Storehouse of beauty and utility--Utah's quaking aspen. UTAH, 10(9): 16-17:29-30. Sept. 1948.

Ellison, Lincoln. Bettering management of Utah's range lands. UTAH, 10(9):8-13:25-27. Sept. 1948.

Fenley, John M. Oldman wormwood...ornamental sagebrush makes good plant for erosion control and sheep grazing. The Utah Farmer, 67:13. March 25, 1948.

______________. Sand dune control in Les Landes, France. Jour. Forestry, 46:514-19. July 1948.

______________. The forestry program of Biarritz American University, France. Jour. Forestry, 46:368-71. May 1948.

Hull, A. C., Jr. Depth, season, and row spacing for planting grasses on southern Idaho range lands. Jour. Amer. Soc. Agron., 40:960-69. Nov. 1948.

______________. and George Stewart. Replacing cheatgrass by seeding with perennial grass on Idaho range lands. Jour. Amer. Soc. Agron. 40:694-703. August 1948.

Hurd, R. M. A range test of species adaptability. Iowa State Coll. Jour. of Sci., 22:387-94. 1948. July 1948.

Lobenstein, Henry. Flood control surveys propose safeguards for Utah's farmlands, industries and homes. UTAH, 10(9):22-23:32-34. Sept. 1948.

Roth, A. H., Jr. Evaluation of public range-watersheds. Proc. Western Farm Economics Assoc., 20:45-50. 1947 (Multilithed in 1948).

______________. Needed: A method of western mountain land valuation. Land Economics, 24-181-85. May 1948.

Stewart, George. Reseeding means more forage for range lands. UTAH, 10(9):18-21:30-33. Sept. 1948.

______________ and A. Perry Plummer. Reseeding range lands by airplane in Utah. Utah Acad. Sci., Arts and Letters. Proc. 24:35-39. 1947 (Published in 1948.)

Taylor, Marion H. and J. F. Pechanec. The stump-jump plow for sagebrush land. Western livestock, 33:35:105-109. .December 1947. (Not included in 1947 report.)

C. Miscellaneous mimeographed reports.

Bleak, A. T. Heavy stocking - a handicap to range sheep production. Station Research Paper 17. 6 pp. December 1948.

Hull, A. C., Jr., and George Stewart. Seeding northern Idaho range lands by airplane. Station Research Paper 16. 14 pp. April 1948.

Roth, A. H., Jr. An economic analysis of public grazing problems in central Utah. Station Research Paper 15. 28 pp. March 1948.

II. Departmental publications scheduled for the remainder of the fiscal year 1949.

Craddock, G. W., and C. R. Hursch. Watersheds and how to care for them. U.S.D.A. Yearbook, 1949.

Ellison, Lincoln, A. R. Croft, and Reed W. Bailey. Indicators of conditions and trend on high-range watersheds of the Intermountain region. U.S.D.A. Pub.

Hutchings, Selar S., and George Stewart. Management of winter sheep ranges in the Intermountain region. U.S.D.A. Cir.

Pechanec, J. F., and George Stewart. Grazing spring-fall sheep ranges of southern Idaho. U.S.D.A. Cir. 808.

III. Manuscripts intended for departmental publication during the fiscal year 1950.

Hutchings, Selar S. Correlation of yearling fleece weights with fleece weights produced by the same animals at two and three years of age. Jour. Agr. Res.

Plummer, A. Perry, and J. M. Fenley. Seasonal plantings in the subalpine zone in central Utah. U.S.D.A. Cir.

_____________ and N. C. Frischknecht. Improving germination and emergence of Indian ricegrass (*Oryzopsis hymenoides*). Jour. Agr. Res.

Reseeding Staff. Seeding Intermountain range lands. U.S.D.A. Farmers' Bul.

Stewart, George, *et al.* Sagebrush eradication. U.S.D.A. Farmers' Bul.

IV. Manuscripts intended for outside publication, 1949.

Watershed Management

Bailey, Reed W. Water control through watershed management. United Nations Sci. Conf. on the Conserv. and Utilization of Resources.

Croft, A. R. Epicycles of erosion in Bairs Canyon, Utah Acad. Sci., Arts, and Letters, Proc.

_____________. Summer storm characteristics in northern Utah. Amer. Geophys. Union Trans.

Lull, Howard W. Artificial snow drifting. Jour. Forestry.

_____________. Forest influences: growth of a concept. Jour. Forestry. (Accepted for publication.)

_____________. Watershed condition and flood potential. Jour. Forestry. (Accepted for publication.)

_____________ and Lincoln Ellison. Precipitation in relation to altitude in central Utah. Amer. Geophys. Union Trans.

Packer, Paul E. An approach to watershed protection criteria. Amer. Geophys. Union Trans.

Reseeding

Blaisdell, J. P. Competition between sagebrush seedlings and reseeded grasses. Ecology.

Fenley, John M. A comparison of several seeding methods in Nevada sagebrush lands.

__________. Railing may be the answer on certain Nevada reseeding jobs.

__________. Reseeding opportunities in Nevada. Nevada Ext. Ser. Bul.

Frischknecht, N. C. and A. Perry Plummer. A simplified technique for determining herbage production on range and pasture land. Agron. Jour. (Accepted for publication.)

Hull, A. C., Jr. Growth periods and herbage production of cheatgrass and reseeded grass species in southwestern Idaho. Jour. Range Mangt.

Hurd, R. M. Grazing crested wheatgrass pastures in Nevada. Jour. Range Mangt.

__________. Sagebrush to grass at Ruby Valley, Nevada. Amer. Cattle Prod. (Accepted for publication.)

Plummer, A. Perry. Kochia--Ornamental garden plant makes good forage...Livestock like it. The Utah Farmer.

Stewart, George. Accomplishments in range reseeding. Natl. Wool Grower.

__________. Range reseeding by airplane as compared with standard ground methods. Agron. Jour. (Accepted for publication.)

__________. Reseeding research in the Intermountain region. Jour. Range Mangt.

__________. The history of crop varieties in Utah. Centennial History of Utah.

__________. The history of the use of public land resources in Utah. Centennial History of Utah.

Stewart, George. Utah's biological heritage and the need for its conservation. Utah Acad. Sci., Arts and Letters. Proc. Vol. 25.

Stewart, George and A. C. Hull, Jr. Cheatgrass (*Bromus tectorum* L.)--an ecologic intruder in southern Idaho. Ecology. (Accepted for publication.)

Grazing Management

Blaisdell, J. P., and J. F. Pechanec. Effects of herbage removal at various dates on vigor of bluebunch wheatgrass and arrowleaf balsamroot. Ecology. (Accepted for publication.)

Ellison, Lincoln. The ecological basis for judging condition and trend on mountain range land. Jour. Forestry.

————————. The establishment of vegetation on depleted subalpine range as influenced by microenvironment. Ecological Monographs. (Accepted for publication.)

————————. Use of indicators for judging condition and trend of high mountain range lands. Jour. Range Mangt.

Hutchings, Selar S. Correlation of fleece weight produced by ewes at one, two, and three years of age. Natl. Wool Grower.

————————. Rehabilitation of winter ranges. Pacific Spectator.

Julander, Odell. Deer-cattle competition. Jour. Forestry.

———————— and J. G. Smith. Deer-sheep competition. Jour. Forestry.

———————— *et al.* Utah's big game livestock range relationships. Utah State Fish and Game Dept. Leaflet.

Major, Jack. Elements of a range condition classification of the aspen type in Utah. (Abstract) Utah Acad. Sci., Arts and Letters Proc.

McGinnies, W. J. Hazards of sheep grazing during severe winters.

Smith, J. G. Deer forage observations in Utah. Jour. Wildlife Mangt.

Flood Control Surveys

Olson, O. C. Relations between accelerated erosion and soil depth on the Wasatch Mountains. Soil Science. (Accepted for publication.)

V. Miscellaneous mimeographed reports to be completed in 1949.

Fenley, John M. A preliminary report on the Buttermilk Reseeding project. Station Research Paper.

Hurd, R. M. Progress report on the Ruby Valley reseeding project. Station Research Paper.

__________. and R. O. Peterson. Outline guide for reseeding ranges in southern Idaho. Cooperative with Idaho Ext. Ser.

Intermountain Station. Publications of the Intermountain Forest and Range Experiment Station, 1913-48.

Klomp, Gerard J. A preliminary report on the use of Agropyron cristatum and Artemisia tridentata as site factor indicators. Station Research Paper.

Major, Jack. Judgment of condition in the aspen type of the Intermountain region. Station Research Paper.

Packer, Paul E. Improved infiltrometer. Station Tech. Note.

Plummer, A. Perry. Seeding tarweed areas in the Intermountain region. Station Research Paper.

STATION PERSONNEL - C. Y. 1948

ADMINISTRATION

Reed W. Bailey	Director
Irene P. Muir	Secretary
Joel F. Walters	Editor
Walter E. Mann	Administrative Assistant
Marguerite A. Israelson	Clerk
Leona H. O'Donnell	Clerk
Lillian Eastman	Clerk
Kenneth L. Winn	Clerk
Marion R. Pearson	Clerk-Steno.
Bernice P. Shelby	Clerk-Steno.
Vendla K. Roberts	Clerk-Typist
Harry W. Pledger	Foreman C&M

RANGE RESEARCH

Grazing Management

Lincoln Ellison	Range Conservationist (R)
Clark E. Holscher	Range Conservationist (R)
Odell Julander	Range Conservationist (R)
Selar S. Hutchings	Range Conservationist (R)
James P. Blaisdell	Range Conservationist (R)
Jack Major	Range Conservationist (R)
William J. McGinnies	Range Conservationist (R)
Paul E. Hansen	Range Aid (Research)
Rudolf Glauser	Range Aid (Research)
Evan R. Johnson	Clerk-Steno.

Range Reseeding

George Stewart	Range Conservationist (R)
Richard M. Hurd	Range Conservationist (R)
Gerard J. Klomp	Range Conservationist (R)
A. Perry Plummer	Range Conservationist (R)
Alvin T. Bleak	Range Conservationist (R)
John M. Fenley	Range Conservationist (R)
Neil C. Frischknecht	Range Conservationist (R)
Ralph C. Holmgren	Range Conservationist (R)

FOREST AND RANGE ECONOMICS

Henry Gilbert White	Forest Economist

FOREST AND RANGE INFLUENCES

George W. Craddock	Forester (Forest Influences)
A. Russell Croft	Forester (Forest Influences)
Paul E. Packer	Forester (Forest Influences)

FOREST AND RANGE INFLUENCES (cont.)

Howard W. Lull	Forester (Forest Influences)
Richard B. Marston	Forester (Forest Influences)
Howard K. Orr	Forester (Forest Influences)
Alden Blain	Conservation Aid

FLOOD CONTROL SURVEYS

Henry L. Lobenstein	Forester (Research Adm.)
John A. Adams, Jr.	Engineer (Civil)
Elon H. Bomberger	Forester (Forest Influences)
J. Marvin Rosa	Hydrologist
Clayton N. Weaver	Forester (Forest Influences)
Albert R. Blanch	Forester (Forest Influences)
Olaf C. Olson	Soil Scientist
Harold H. Price	Forester (Forest Influences)
Vincent W. Twoomey	Forester (Forest Influences)
George W. Carlson	Forester (Forest Influences)
William E. Murray	Forester (Forest Influences)
Merle H. Tigerman	Forester (Forest Influences)
Byron F. Thurmond	Cartographic Engineer
Richard W. Payne	Engineering Draftsman

FOREST MANAGEMENT

James D. Curtis	Forester (Research Adm.)
Robert W. Richman	Research Forester